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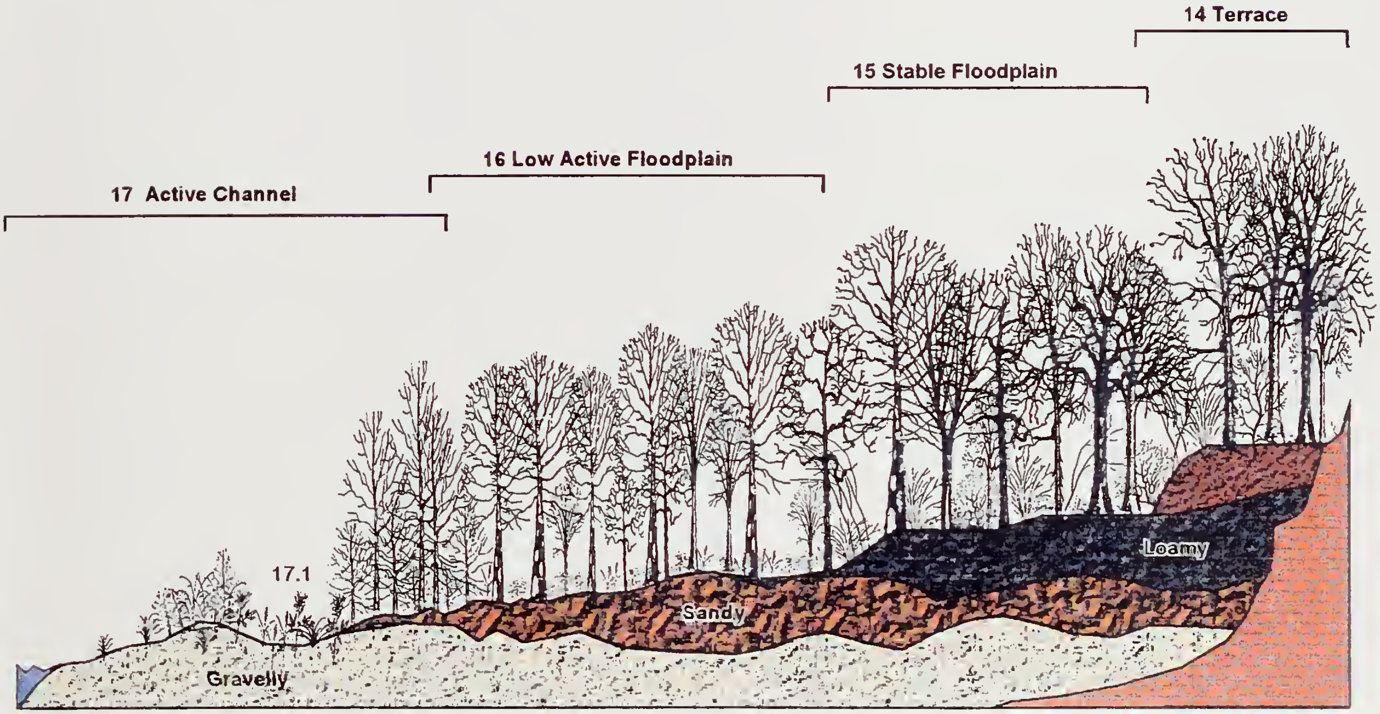
ECOLOGICAL CLASSIFICATION OF RIPARIAN AREAS IN THE OZARK NATIONAL SCENIC RIVERWAYS



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Ecological Classification of Riparian Areas in the Ozark National Scenic Riverways

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INTRODUCTION

Riparian ecosystems are composed of a complex suite of interdependent environmental factors interacting with vegetation patterns over time. Along a river system, a mosaic of fluvial landforms is maintained through the differential deposition and erosion associated with past and contemporary flood events (Gregory et al. 1991; Gordon et al. 1992). Riparian vegetation research has identified flood frequency, soil characteristics, and elevation above and distance from the river channel as important determinants of plant species distributions (Hupp and Osterkamp 1985; Nillson et al. 1989; Naiman and Decamps, 1990; Gregory et al. 1991; Bendix 1994; Siebel and Bouwma 1998). On a given fluvial landform, vegetation change over time can be multidirectional depending on whether flooding is erosional or depositional. For example, an annual flood event may inundate a low floodplain for a number of days without disruption to the vegetation community while a 50-year flood may alternately scour and deposit sediments across the floodplain and result in extensive tree tip-over and understory and ground flora mortality.

Riparian ecosystems can be logically described by relating fluvial landform and associated environmental characteristics to vegetation. These physical characteristics, formed over time through flooding patterns, reflect the hydrologic regime of the river. Kovalchik (1987) recognized that riparian vegetation dynamics is associated with the changes in soil and water characteristics as the river channel and water-movement patterns shift. By linking riparian vegetation with these physical features, we can begin to recognize riparian ecosystems with identifiable biological and physical characteristics.

The Ozark National Scenic Riverways (OZAR) is a long, linear park centered on the Jacks Fork and Current rivers and the associated riparian zones. Understanding riparian ecosystems is an essential element of resource management in the park. Studies by Steyermark (1940) and Witherspoon (1971) identified successional stages in riparian vegetation but linked them only loosely to physical factors. Other studies at OZAR and along nearby Ozark streams have described the structure, diversity, and dynamics of these fluvial systems but focused mainly on the physical environment (Jacobson and Pugh 1992, Albertson et al. 1995, Jacobson 1995, McKenney et al. 1995). Most recently, Lyon and Sagers (1998) identified strong relationships between riparian vegetation and environment along the Current and Jacks Fork rivers but did not develop a classification of riparian ecosystems. An ecological classification system that links vegetation to physical factors within the riparian zone of the park is still needed to provide resource managers with a framework for ecosystem management.

Purpose and Objectives

The purpose of this study was to develop an ecological classification system within the riparian zone of the park and to provide a framework for long-term monitoring. Our specific objectives were to (1) identify and describe vegetation and environmental relationships within the riparian zone of the Jacks Fork and Current rivers, (2) develop Ecological Landtypes (ELTs) and Ecological Landtype Phases (ELTPs) for use in the Missouri Ecological Classification System Project (ELTs and ELTPs are site-level land units described by similarities in vegetation, soil, geology, and landform between 10 to100 acres [3.5 to 35 ha] in size [Meinert et al. 1997]), and (3) establish a set of permanent plots for long-term monitoring of riparian ecosystems on OZAR. Products include detailed information on plot location and establishment, baseline vegetation and environmental data, and a multifactor riparian classification system for OZAR.

STUDY AREA

Location

OZAR was established in 1964 to encompass a 75,000 ac (26,306 ha) tract in Dent, Shannon, Carter, and Texas counties in the Ozark Highlands in Missouri. OZAR is a long, linear park encompassing the riparian corridor and adjacent upland along a 161 km portion of the Current River and a 55 km portion of the Jacks Fork River.

The Ozark Highlands is an assemblage of nearly level to deeply dissected plateaus comprised primarily of Ordovician dolomites and sandstones. Clear, spring-fed streams have cut deeply into the plateaus, forming a region of steep to moderately rolling hills with local relief of mainly 60 to 150 m (200 to 500 ft) but occasionally to 300 m (1,000 ft) (Meinert et al 1997).

The Ozark Highlands has been divided into 17 ecological subsections (Keys and Carpenter 1995) based mainly on variations in relief, geologic parent materials, soils, and vegetation patterns (see Figure 1). OZAR is located in the Current River Hills subsection, a region encompassing the moderately rolling to steeply dissected hills associated with the Current, Jacks Fork, Eleven Point, and Black rivers. The Current and Jacks Fork rivers are two of the major river systems within the Current River Hills subsection. A karst drainage system characterized by dendritic and radial drainages underlies most of the region; as much as 60 % of the water flow in the Jacks Fork and Current rivers originates in karst springs (Barks 1978). Average yearly rainfall ranges from 1.08 m (42 in) at the headwaters of the Current River in Dent County to 1.14 m (45 in) in southern Carter County (U.S. Department of Commerce, National Weather Bureau 1968). Typical yearly flood levels on both the Jacks Fork and Current rivers range from 2 to3 m (6.5 to 9.8 ft) above baseflow; a typical 25- to 50-year flood reaches 4 to 6 m (13.1 to 19.7 ft) above baseflow (Jacobson and Primm 1994).

Vegetation

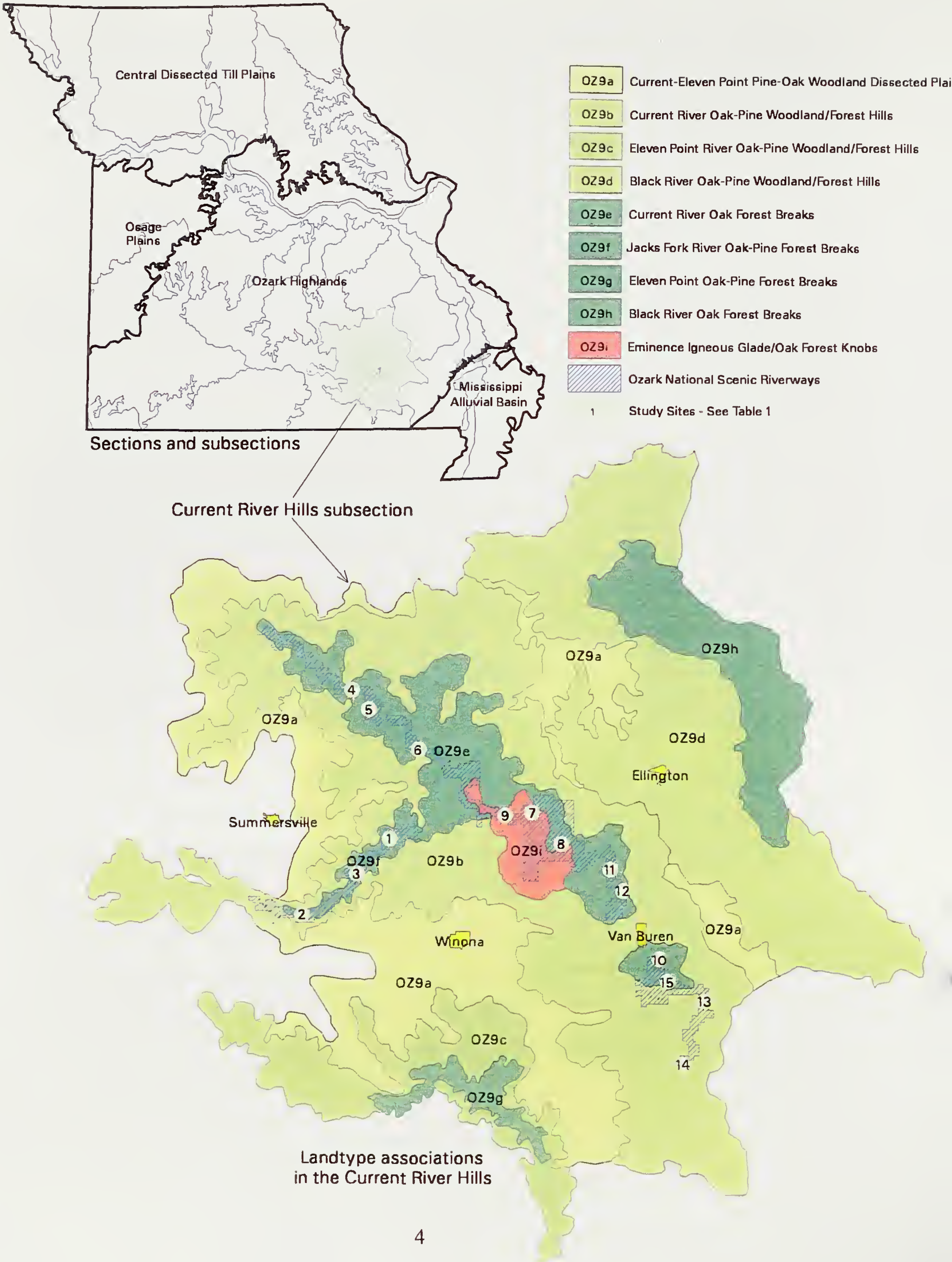
The natural vegetation of the region consists mainly of oak-hickory and oak-shortleaf pine forests and woodlands, oak savanna, and glades. Bottomland hardwood forests are found along the major river systems. Today, most Ozark forests are second- and third-growth forests. Large-scale timber exploitation at the turn of the century (1880 to 1920) removed most usable timber. Bottomland forests were not spared from the clearcutting, agricultural clearing, and grazing that characterized this timber boom period. The Current and Jacks Fork, as fast-moving rivers, were also used to facilitate the transfer of logs from site to mill. The effects of past use on hydrologic pattern and process and on the vegetation communities are poorly understood.

METHODS

Sampling Design

To ensure an adequate distribution of samples, we divided OZAR into five segments according to Landtype Associations (LTA) (Nigh et al. in progress). LTAs are landscape-scale units, 10 to 100 sq mi (5 to 40 sq km) in size that are delineated by local climate, topography, geologic parent material, soil associations, and potential vegetation alliances (Meinert et al. 1997). Within each LTA, we chose three sites for sampling from a pool of potential sites identified from aerial photo interpretation and field and aerial reconnaissance.

Figure 1. Study site area and ecological units


Central Dissected Till Plains
Osage Plains
Ozark Highlands
Mississippi Alluvial Basin
Sections and subsections
Current River Hills subsection
OZ9a Current-Eleven Point Pine-Oak Woodland Dissected Plai
OZ9b Current River Oak-Pine Woodland/Forest Hills
OZ9c Eleven Point River Oak-Pine Woodland/Forest Hills
OZ9d Black River Oak-Pine Woodland/Forest Hills
OZ9e Current River Oak Forest Breaks
OZ9f Jacks Fork River Oak-Pine Forest Breaks
OZ9g Eleven Point Oak-Pine Forest Breaks
OZ9h Black River Oak Forest Breaks
OZ9i Eminence Igneous Glade/Oak Forest Knobs
▨ Ozark National Scenic Riverways
1 Study Sites - See Table 1
OZ9a
OZ9h
OZ9a
OZ9d
OZ9e
Ellington
Summersville
OZ9i
OZ9f
OZ9b
Winona
Van Buren
OZ9a
OZ9a
OZ9c
OZ9g
1
2
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4
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10
11
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13
14
15
Landtype associations in the Current River Hills

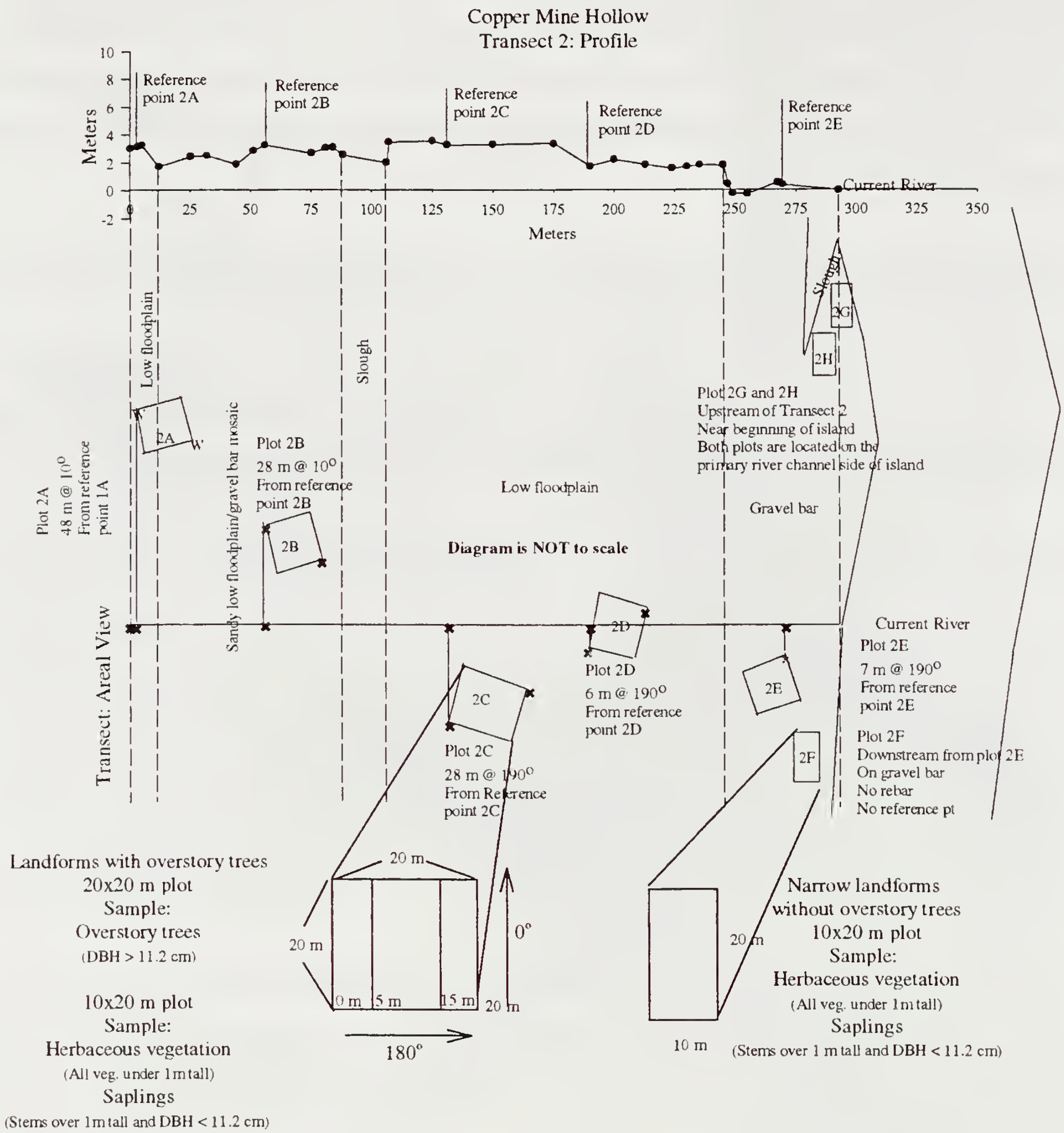
For a site to be selected, it had to exhibit minimal human disturbance (e.g., without evidence of logging in the past 50 years and with absence of homesteads, remnant roads, and old fence rows). We were interested in sites that contained a variety of the different fluvial landforms present along the length of the river, including active channels, low and high floodplains, and low terraces. During 1998, we established a total of 15 sites and 159 plots in the five LTAs (see Figure 1 and Table 1).

Table 1. Sites sampled within each Landtype Association. The four landform types used in site stratification were active channel (CH), low floodplain (LFP), high floodplain (HFP), and terrace (TER).

Landtype Association	Sample sites (number of plots sampled)	Total number of plots	Total number of plots per landform type			
			CH	LFP	HFP	TER
Jacks Fork River Breaks	1. Alley Spring (15) 2. Bear Hollow (8) 3. Island Branch (9)	32	8	18	6	-
Upper Current River Breaks	4. Cave Spring (6) 5. Pulltite Spring (11) 6. Round Spring (14)	31	11	10	8	2
Eminence Knobs	7. Blair Creek (15) 8. Cardareva Bluff (4) 9. Two Rivers (11)	30	11	10	7	2
Lower Current River Breaks	10. Chickopee (7) 11. Dick Path Hollow (12) 12. Spring Hollow (10)	29	11	13	5	-
Lower Current River Hills	13. Copper Mine Hollow (15) 14. Gooseneck Hollow (13) 15. Long Bay (9)	37	12	12	13	-

Each site was first divided into three areas, upstream, middle, and downstream, within which we randomly located one transect positioning it from the hillslope to the river's edge and perpendicular to the channel. We classified all land features crossed by the transect line as one of four landform types using land surface height, position, and shape; evidence of flooding activity; and surface soil characteristics (Albertson et al. 1995). The four landform types were active channels or gravel bars, low floodplains, high floodplains, and terraces (see Table 2). A stratified random sampling design was used to place plots along each transect with landform designations operating as sampling strata (see Figure 2 example). The number of plots located along a transect depended on the number of different landforms crossed by the transect line and the extent of each landform.

Figure 2. Example of a transect profile, plot location diagram, and plot diagrams for Copper Mine Hollow Transect 2.



We randomly located plots within 50 m of the transect on either side within the bounds of a landform. We used a random numbers table to decide location along the transect and the distance from the transect. We established plots on floodplains and terraces that were at least 30-m wide and on active channels at least 15-m wide. For all landforms that met this width criteria, at least one plot was randomly located within it. For landforms greater than 100-m wide, an additional plot was added for each 100 m total length.

Table 2. Landform definitions used to stratify the riparian landscape for plot establishment (adapted from Albertson et al. 1995).

Landform	Description
Active channel	Extremely gravelly soils Active erosion or deposition Surface highly dissected to smooth Flooding debris size small to large Floods multiple times per year T_0/T_1 surface (Albertson et. al. 1995)
Low floodplain	Sandy and very gravelly sandy soils (gravels often buried) Some erosion or deposition Surface wavy to smooth Flooding debris size medium to small Floods at least once a year T_1/T_2 surface
High floodplain	Loamy, gravelly loamy, and silty soils Surface smooth to flat Flooding debris size small Floods occasionally (less than once a year) T_3 surface
Terrace	Soil development; argillic horizon present Loamy and silty soils Surface elevated flat Flooding debris size small to none Floods rarely (less than 10 times in 100 years) T_4/ T_5 surface

To facilitate relocation of plots, we created maps and establishment records for each site, transect, and plot. Additionally, we permanently marked the hillslope end of each transect and the reference points along the transect that were associated with plot locations with rebar and witness trees marked with numbered aluminum tags (see Figure 2). All plots were referenced to the transect line and permanently marked with rebar at the northeast and southwest corners. Active channel plots were not marked with rebar because storms would likely claim any positioned rebar. We determined transect end points, plot reference points, and plot corner locations using a global positioning system receiver. We provided detailed monitoring records and plot location data to OZAR staff independent of this report.

Field Procedures

At each plot, we recorded the following environmental variables: elevation above river; distance from river; depth, texture and designation of all soil horizons; depth to free water; soil parent material; and a categorical descriptor of flooding activity. We measured elevation using a clinometer and leveling rod, surveying an elevational cross section along each transect (see Figure 2). Distance from river was measured using the transect line as a reference. We described each plot as an erosional, depositional, or stable feature to categorize flooding activity. We collected soils data during the winter of 1998. Soil pit information collected included the depth, texture, and designation of all horizons to a depth of 1.22 m (48 in) and depth to free water. We categorized soil parent material (alluvium-derived) into one of the following: gravel, gravel and sand, sand and gravel, sand, loam and gravel, loam, or silt.

Most plots we sampled measured 20 m by 20 m; we used smaller 10 m by 20 m plots on active channel features less than 20-m wide (see Figure 2). We sampled *overstory trees* (stems > 11.4 cm, or 4.5 in diameter at breast height [dbh]) in the 20 m by 20 m plot, identified each tree, and measured it to the nearest 0.1 cm dbh. We sampled *shrubs and saplings* (stems < 11.4 cm or 4.5 in dbh) in an interior 10 m by 20 m subplot, identified each species and measured it to the nearest 0.1 cm dbh. Plot data for the overstory and shrub and sapling layers was summarized by species stem density and basal area. Plot data was also summarized by calculating importance value for each species.

$$\text{Importance Value}_{species\ i} = \frac{\text{Relative \% Frequency} + \text{Relative \% Density}}{2}$$

For the overstory and understory layers, species importance value and stem density were used in subsequent analyses.

In a *ground flora* releve of the 10 m by 20 m subplot, we identified to species all herbaceous and woody species less than 1 m tall. We assigned all ground flora species a *cover-class* value reflecting the percentage of ground covered by that species within the releve. We used the following cover classes: R (rare) = trace cover and less than three individuals, 1 = 0 to 0.99 % cover, 2 = 1 to 5 % cover, 3 = 6 to 15 % cover, 4 = 16 to 25 % cover, 5 = 26 to 50 % cover, 6 = 51 to 75 % cover, and 7 = 76 to 100 % cover. Nomenclature follows Steyermark

(1963). The cover-class values were converted to the midpoint percentage value of each cover-class and used in all analyses.

Statistical Analyses

We used a combination of Detrended Correspondence Analysis (DCA) and Correlation Analysis, Cluster Analysis (CA), Two-Way Indicator Species Analysis (TWINSPAN), and Multi-Response Permutation Procedure (MRPP) to investigate vegetation-environmental relationships and derive classification types and riparian species groups. This was an iterative process, with the results successively revising the classification.

Vegetation-Environmental Relationships. DCA (Hill and Gauch 1980) was used to assess broad species-environment relationships. We used species importance values (IV) in the overstory and understory analyses, and the midpoint cover-class values for ground flora analyses. We used biplots and two axis ordination diagrams to display DCA results. In DCA, plots represented by points found closer together in ordination space were more similar in species composition than plots represented by widely separated points. We used the ordination axes to interpret change in beta diversity; and used species-plot figures, and environmental and species overlays to elucidate species-environment relationships (Kent and Coker 1994). We performed Spearman (Rank) correlation analyses of the environmental variables collected at each plot with DCA axes.

DCA and correlation analysis identified the variables, parent material and soil texture, elevation above river, and distance from river as strongly related to the distribution of plots along DCA axis 1. To further explore variation in vegetation, we separated the data set into categories based on the physical characteristics; landform, parent material, and soil horizon characteristics. We placed plots located on gravel bars and low floodplains with sand and loamy sand soil with gravel in the top 0.51 m (20 in) of soil into an Active Channel (AC) category and plots located on active low and high floodplains with sand and loamy sand soil with or without gravel present below 0.51 m (20 in) in an Active Floodplain (AFP) category. We placed plots located on high floodplains and terraces with silt, silt loam, loam, and sandy loam soils in a High Floodplain and Terrace (HFPT) category.

We divided the overstory, understory, and ground flora data sets into the above-mentioned categories and performed Cluster Analysis (CA) on the overstory, understory, and ground flora using basal area, stem density, and percent foliar cover, respectively. CA is an agglomerative classification technique that progressively combines plots based on species similarity until all plots are within one group. We used relative Euclidean distance measure and Ward's group linkage method in the analyses. We were interested in whether within category differences in vegetation, such as differences in vegetation among plots on high floodplains or among plots on active channels were present.

Classification and Validation. From CA, plot groups based on vegetation similarities were formed for each category. These plot groups were compared across vegetation layer for plot membership, i.e. plots that occurred in one group in the overstory that also occurred together in the understory. Plot groups linked across two or three vegetation layers were identified as ELT Phases (ELTP). Plots that did not link across at least two vegetation layers were not identified as an ELTP, but instead the plot-level vegetation characteristics were compared to plots from other plot groups for similarities in vegetation. From this iterative process, the three categories and associated plot groups gave rise to four ELTs and eight ELTPs.

We tested for floristic differences between ELTs and ELTPs using MRPP. MRPP is a nonparametric analogue of linear discriminant analysis, similar to the *t*-test and the one-way analysis of variance *F* test. However, the relaxed requirements on the data structure for MRPP allow for its application with multivariate data (Zimmerman et al. 1985). MRPP tested the hypothesis of no difference between the floristic composition of the overstory, understory, and ground flora for all possible combinations of paired ELTs and ELTPs. We investigated differences in environmental variables at the ELT and the ELTP levels through summary figures and graphs.

Riparian Ecological Species Groups. Two Way Indicator Species Analysis (TWINSPAN) was performed on the ground flora using a reduced data set of species that occurred in at least 50% of the plots within an ELT. TWINSPAN simultaneously classifies species and samples and presents the information in a final ordered two-way table (McCune and Mefford 1995). Species names are arrayed along the left side of the table and sample numbers are along the top. The pattern of zeros and ones on the right and bottom sides of the table define the dendrogram of the classification. The interior contains the abundance classes, defined by pseudo-species cut levels, of each species in each sample. From the two-way output, one can identify which species are most strongly related to a group of plots. Groups of plots were investigated for their membership to ELTs and ELTPs; a close match between TWINSPAN plot groups and ELTs was found. The riparian species groups were identified as those species with consistently high abundance within a TWINSPAN plot group at the second level of division.

ELT and ELTP Characterization. The final stage in the analyses was to characterize the composition and structure of the vegetation and the means and ranges in variability of environmental factors across ELTPs. We were interested in investigating the relationships of ELTPs to previously described vegetation successional pathways for Ozark vegetation (Steyermark 1964 and Witherspoon 1971). We assigned the common woody species a successional index value (SIV) of 1 through 4 reflecting their distribution along a successional gradient from early to later successional species (adapted from Witherspoon 1971). Type I species (SIV = 1) included river birch (*Betula nigra*), Ward's willow (*Salix caroliniana*), sandbar willow (*S. interior*), black willow (*S. nigra*), and willow (*S. rigida*). Type II species (SIV= 2) included box elder (*Acer negundo*), silver maple (*A. saccharinum*), and sycamore (*Platanus occidentalis*). Type III species (SIV = 3) included hackberry (*Celtis occidentalis*), white ash (*Fraxinus americana*), green ash (*F. pennsylvanica*), American elm (*Ulmus americana*), and red elm (*U. rubra*). Type IV species (SIV = 4) included sugar maple (*A. saccharum*), bitternut hickory (*Carya cordiformis*), oak spp. (*Quercus* spp.), pawpaw (*Asimina triloba*), and spicebush (*Lindera benzoin*).

We identified a subset of plots (113 of 159, or 71%) where the above species comprised 75% of the plot importance value. For each plot, we weighted (multiplied) the importance value of the species listed above by their SIV. We summed the weighted importance values by plot and produced Cumulative Successional Index Values (CSIV) (mean and standard error) for each ELTP. Because of the strong *a priori* relationship of distance from and elevation above river to vegetation of increasingly later successional status, we also calculated a Distance-Elevation Index, a combined value for relative elevation above and relative distance from the river:

$$\text{Relative elevation (RELEV)} = ELEV_{plot} / ELEV_{highest\ for\ site}$$

$$\text{Relative Distance (RDIST)} = DIST_{plot} / DIST_{farthest\ for\ site}$$

$$\text{Distance-Elevation Index}_{plot} = RELEV + RDIST$$

This index was used with the CSIV to further investigate the relationship between vegetation succession, landform, and flood frequency along Ozark river systems.

RESULTS AND DISCUSSION

Floristics

Floristic summaries of all species sampled during the study are found in Appendix A (woody vegetation) and Appendix B (ground flora vegetation). Within the study area, we identified a total of 66 woody species, 60 of which occurred in the understory and 38 of which were in the overstory. Four species, shellbark hickory (*Carya laciniata*), mockernut hickory (*Carya tomentosa*), butternut (*Juglans cinera*), and white oak (*Quercus alba*) were only found in the overstory. Within the overstory, sycamore, box elder, and American elm comprised 60% of the total basal area and total density across all plots. Roughly 90% of all overstory species occurred in less than 25% of all plots. In the understory, Ward's willow, spicebush, sycamore, and pawpaw comprised 60% of the total density. These species, along with hackberry, American elm, and the woody vines Virginia creeper (*Parthenocissus quinquefolia*), poison ivy (*Toxicodendron radicans*), and grape (*Vitis spp.*) were the most commonly encountered species, found in more than 25% of the plots.

In the ground flora, 442 species were identified, including 243 native herbaceous forbs, 43 native annual and perennial grasses, and 17 sedges. Forty-nine non-native species were also encountered. *Verbesina alternifolia, Laportea canadensis, Rudbeckia laciniata, Uniola latifolia, Elymus virginica*, *Viola sororia*, and Box elder seedlings were the most common ground flora species, present on more than 65% of all plots. Conversely, roughly 250 species (56%) were present on less than 5% of all plots.

Vegetation-Environmental Relationships

Results from DCA and correlation analysis identified distance from river, elevation above river, depth of A soil horizon, depth to gravel, and % gravel in the profile (weighted mean) as the primary environmental conditions affecting woody and ground flora vegetation distribution patterns (see Figures 3A and B). All of these factors contribute to defining fluvial landforms; each factor results from the flooding that continually shapes and forms fluvial landforms.

For the ground flora, although all variables stated above were significantly correlated ($p \leq 0.01$) with DCA axis 1, distance from river and depth to gravel were most strongly related. Overlays of landform and parent material onto the ground flora ordination identified terrace and high floodplains located toward the positive end of DCA axis 1 and gravel bars and low floodplains located toward the negative end of DCA axis 1. The significant negative correlation

($p \leq 0.05$) of elevation above river with DCA axis 2 appears to reflect differences in the elevation among plots on active channels only. This may be due to the subtle differences in elevation between plots located in extensive scour holes and those located on mounds of gravel resulting from storm events.

For the understory (sapling layer), all variables were significantly correlated ($p \leq 0.01$) with DCA axis 1, with depth to gravel the most strongly correlated variable. As with the ground flora, overlays of landform and parent material displayed high floodplains and terraces and gravel bars at polar axes along DCA axis 1.

In the overstory, all environmental variables were significantly correlated ($p \leq 0.01$) with DCA axis 1. No variables were significantly related to DCA axis 2. Unlike ground flora and understory, overlays of landform and parent material did not provide evidence of a strong relationship between fluvial landform and overstory vegetation. Overstory species are characterized by broader distribution patterns than the understory and ground flora species.

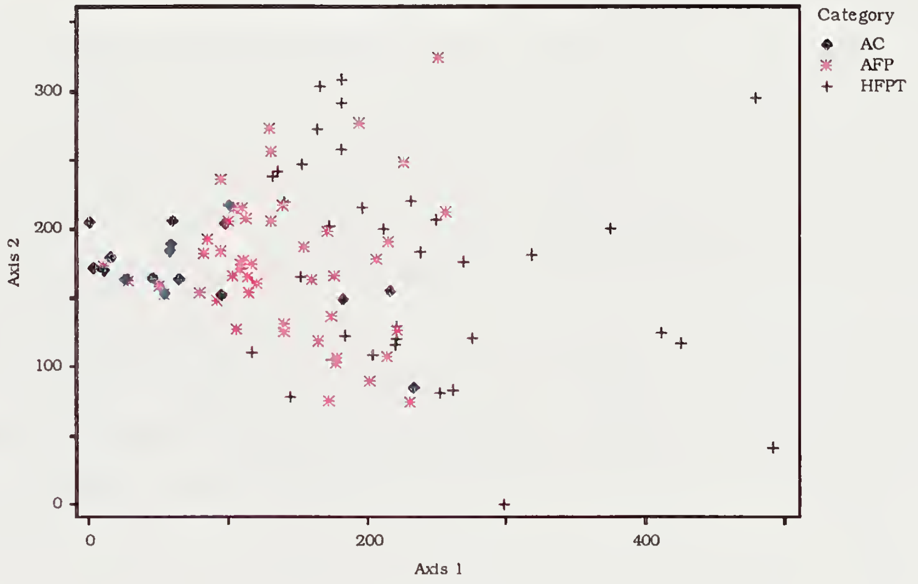
DCA and correlation analysis results confirmed that vegetation patterns were strongly related to fluvial landforms and associated environmental characteristics. This was not a surprise, as the relationship between flooding, fluvial landforms, and vegetation is well-known. In order to move toward a multifactor classification of riparian units, we categorized each plot based on landform, parent material, and soil textural characteristics (refer to *Methods-Vegetation-Environment Relationships* section). While these physically-based categories demonstrated strong relationships to the position of plots in ordination space (and thus vegetation), boundaries were not always distinct, and variation within the categories needed further investigation.

Cluster Analysis (CA) was run on each category separately to investigate within-category differences. For the AFP category, the first division identified a distinct split for overstory and understory vegetation plots (see Figure 4). Plots characterized by sycamore and willow in both vegetation layers separated from plots with varying abundance of other mixed hardwood species in addition to sycamore. For ground flora, CA identified three groups. The plots characterized by *Panicum clandestinum*, *Aster lateriflorus* and poison ivy linked to those plots characterized by sycamore and willow in the overstory and understory. The two other groups, plots characterized by *Laportea canadensis*, *Elymus virginicus*, *Verbesina alternifolia,* and *Rudbeckia laciniata,* were linked to the mixed hardwood-sycamore plots.

Figure 3A. DCA plot ordinations and Spearman rank correlations for the overstory and understroy layers. Environmental variables that are highly significantly correlated ($p \leq 0.01$) with an axis are noted by a double asterisk and environmental variables that are significantly correlated ($p \leq 0.05$) are noted by a single asterisk.

Environmental variables	Overstory axis 1	Overstory axis 2	Understory axis 1	Understory axis 2
Distance from river	0.476 *	0.073	-0.646 *	0.209
Elevation above river	0.498 *	-0.150	-0.625 *	0.245 **
Depth of A horizon	0.390 *	0.008	-0.442	0.052
Depth to gravel	0.516 *	0.057	-0.702 *	0.207
% gravel in profile (weighted mean)	-0.491 *	-0.126	0.593 *	-0.151

Overstory Strata



Understory Strata

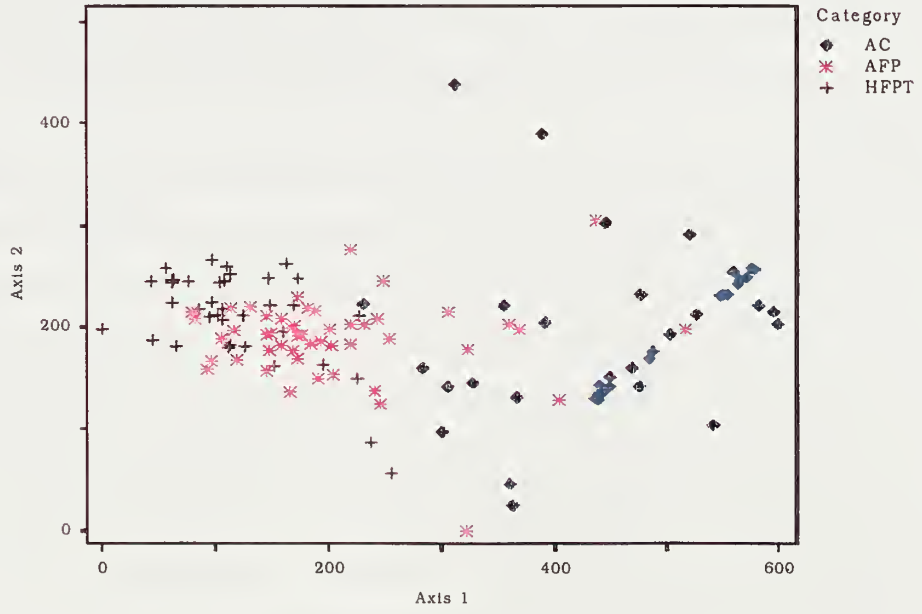


Figure 3B. DCA plot ordinations and Spearman rank correlations for the ground flora layer. Environmental variables that are significantly correlated ($p \le 0.05$) with an axis are noted by a single asterisk.

Environmental variables	Ground flora axis 1	Ground flora axis 2
Distance from river	-0.726 *	-0.374 *
Elevation above river	-0.641 *	-0.641 *
Depth of A horizon	-0.595 *	-0.205
Depth to gravel	-0.796 *	-0.279 *
% gravel in profile (weighted mean)	0.649 *	-0.181

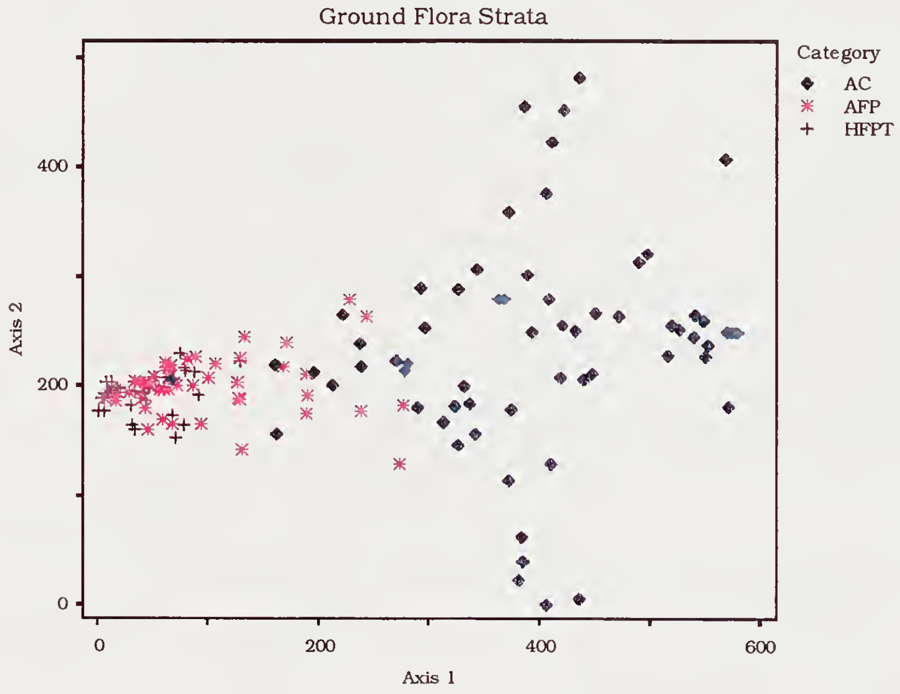
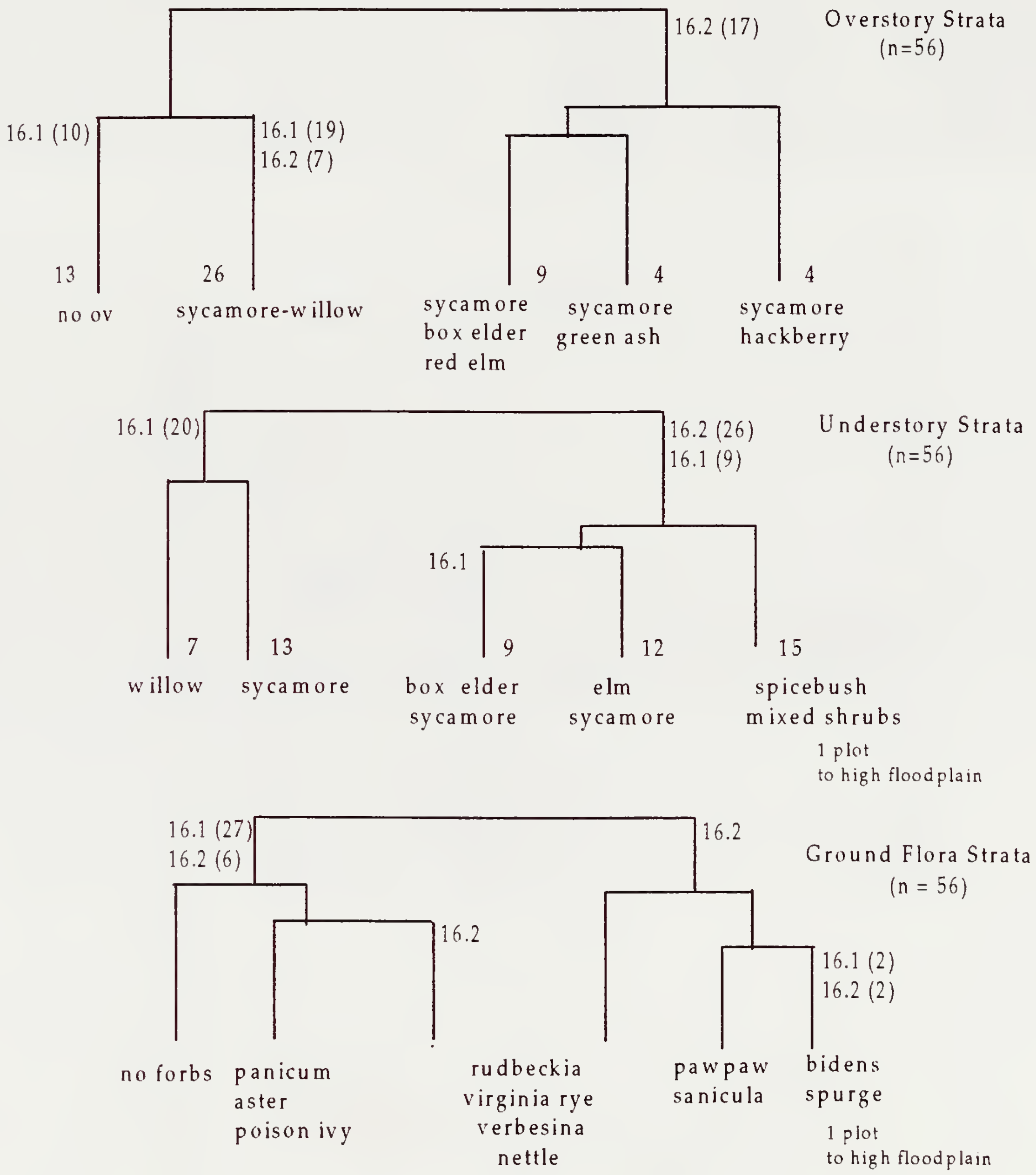


Figure 4. Cluster Analysis dendrograms for the Active Floodplain category. The number of plots identified as high-energy low floodplains is 29, and the number of plots identified as stable low floodplains is 26. Four plots from the Active Channel category were removed from the Active Channel category and identified as high-energy low floodplains, and one plot was removed from the Active Floodplain category and identified as a stable high floodplain. Dominant species and number of plots associated with each major division are illustrated.



For the HFPT category, we identified two groups of plots for both the overstory and understory vegetation (see Figure 5). A group of overstory plots characterized by sycamore and hackberry mixed with red elm was associated with a group of plots in the understory characterized by mixed elm and hackberry. Ground flora analysis identified the same plots grouped together, characterized by *Carex amphibola*, *Uniola latifolia*, *Leersia oryzoides*, and *Laportea canadensis*. A second group of plots was characterized by red elm, box elder, and hackberry. Those same plots grouped together in the understory and ground flora, characterized by pawpaw, and by *Poa sylvestris*, *Desmodium pauciflorum*, *Asarum canadense*, *Phryma leptoctachya,* respectively.

A number of plots were individually investigated in the HFPT category. For each vegetation layer, there was one leg (inside right of the dendrogram for the overstory and understory, inner left of the dendrogram for ground flora) that was difficult to classify. Four of the plots were classified as terraces and classified as a group. Because examples of forested terraces were scarce due to their conversion to cropland and pastureland, we only were able to establish and sample four intact terrace features. The terrace plots sampled had a mixed hardwood overstory of bitternut hickory, chinkapin oak (*Quercus muhlenbergii*), and hackberry; pawpaw, spicebush, and mixed hardwood saplings in the understory; and a mesic upland forest ground flora. From the plot level vegetation summaries, the plots classified with the terraces were placed with either of the two described groups.

Active Channel plots were not analyzed in CA; they were separated into phases based on gross physiognomic differences illustrated in Figure 6.

Validation and Characterization of ELTs and ELTPs

Cluster Analysis allowed us to refine categories into ELTs and within category groups into ELTPs (see Table 3). A set of descriptions of the ELT and ELTPs identified, including text and tabular summaries, are found in Appendix C. This project is part of a larger effort to identify a Missouri Ecological Classification System (MOECS) for the Current River Hills Subsection. The classification units are classified as ELT 14 through 17 in keeping with the MOECS format (See Nigh et al. 2000 for more information on MOECS).

Figure 5. Cluster Analysis dendrograms (simplified) for the High Floodplain and Terrace Category. For ELTP 15.1, n = 17; ELTP 15.2, n = 24*; ELTP 14.1, n = 4. *Note that one plot from the Active Floodplain category is later incorporated into ELTP 15.2. Dominant species, number of plots, and resultant ELTs and ELTPs are illustrated.

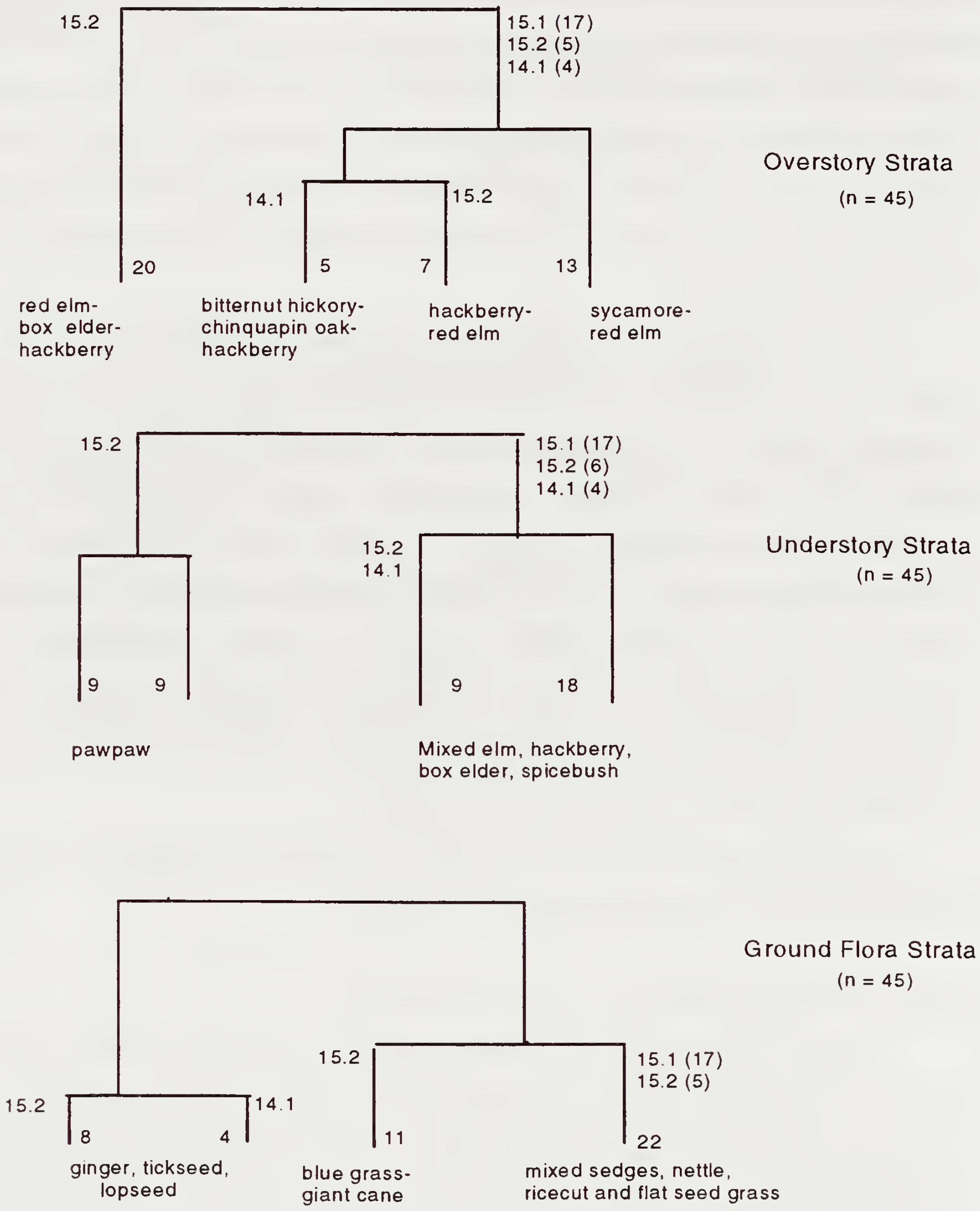
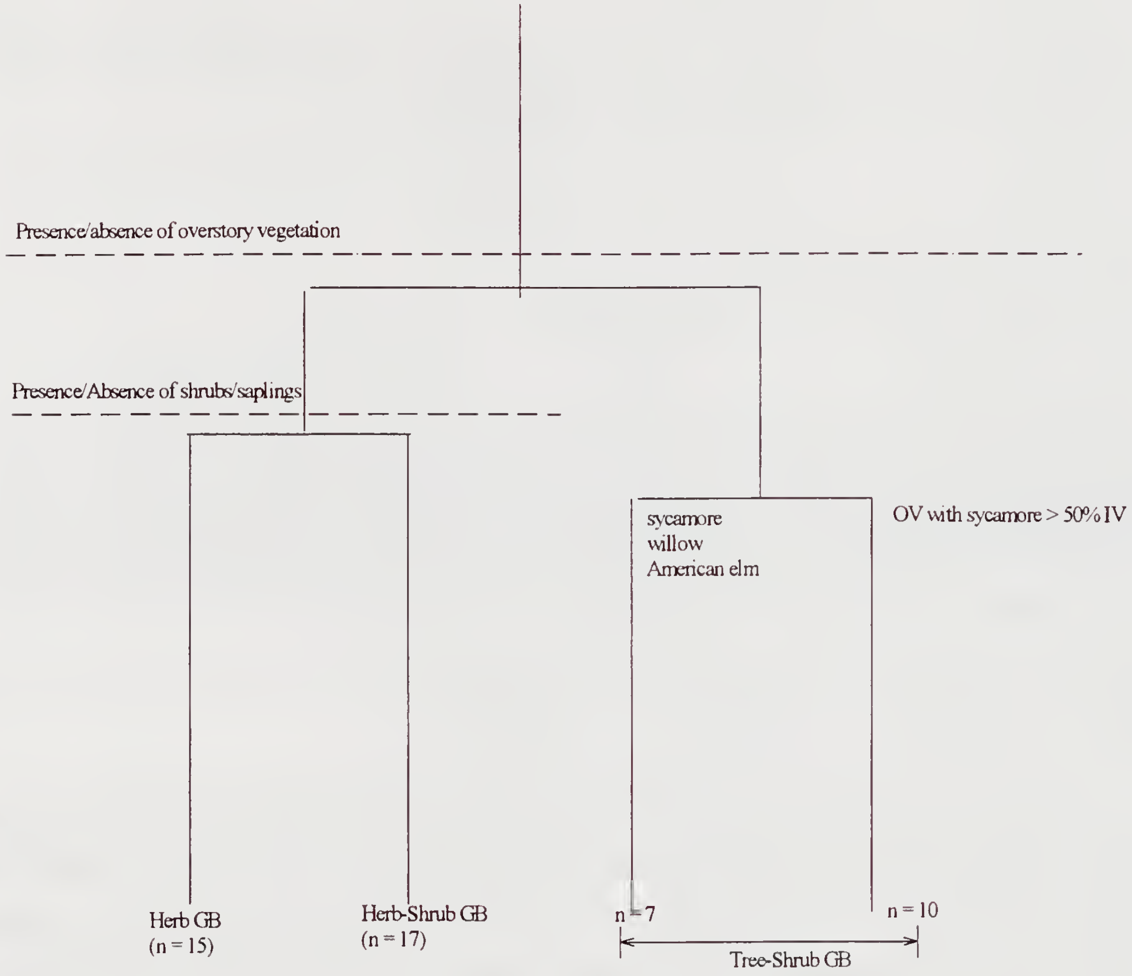


Figure 6. Physiognomic hierarchical classification of the Active Channel category. Classification used in the identification of gravel bar ELT Phases. See Appendix A for species codes and corresponding scientific and common names. GB = gravel bar, OV = overstory, UN = understory, and IV = importance value.


Presence/absence of overstory vegetation
Presence/Absence of shrubs/saplings
sycamore
willow
American elm
OV with sycamore > 50% IV
Herb GB
(n = 15)
Herb-Shrub GB
(n = 17)
n = 7
n = 10
Tree-Shrub GB

The HFPT category was classified into two ELTs, Terrace (ELT 14) and High Floodplain (ELT 15). The terrace plots were classified as Terraces (ELT 14) with one phase identified. The sycamore-hackberry-red elm plots were common on lower, more active parts of the high floodplain and were classified as Active High Floodplains (ELTP 15.1). The box elder-red elm plots were likely associated with higher, more stable high floodplain positions and terraces; they were classified as Stable High Floodplains (ELTP 15.2). The AFP category was classified as an Active Low Floodplain (ELT 16). Field observations suggest that the sycamore-willow plots were characteristic of lower, more active floodplains; this group of plots was classified as a High Energy Low Floodplain (ELTP 16.1). The mixed hardwood plots seemed to occur mainly on higher, more stable low floodplains and were classified as Stable Low Floodplains (ELTP 16.2). The AC category was classified as the Active Channel (ELT 17). Three phases were identified based on differences in community structure: Herbaceous Gravel Bar (ELTP 17.1), Herb-Shrub Gravel Bar (ELTP 17.2), and Tree-Shrub Transition (ELTP 17.3).

Table 3. Ecological Landtypes (ELTs)

Ecological Landtype	Dominant fluvial landform and surface	Flooding regime
Active Channel ELT (n = 45)	Gravel bar (T_0/T_1)	Frequent high-intensity flooding Frequently inundated for long periods of time
Active Low Floodplain ELT (n = 59)	Low floodplain (T_2)	Seasonal high-intensity flooding Inundated seasonally
Stable Floodplain ELT (n = 42)	High floodplain (T_2/T_3)	Seasonal low-intensity flooding High-intensity flooding rare
Terrace ELT (n = 4)	High and low terrace (T_4)	Rarely flooded

Species Composition. The MRPP test for floristic similarity among the ELTs showed highly significant differences for all strata between paired ELTs (see Table 4). MRPP analyses amongst ELTPs also showed significant dissimilarities in vegetation between them as well (see Table 5). While ELTs segregated environmental factors well (see Table 3), data illustrating environmental differences between Phases within an ELT showed no apparent trend. ELTPs were recognized mainly based on variation in vegetation.

Table 4. Multi-Response Permutation Procedure (MRPP) results of the floristic differences between paired ELTs. The MRPP test statistic T was Tau, Kendall's rank correlation coefficient, and $p \le 0.05$ identified those ELTs with significant floristic differences. There were too few terrace samples to test for significance.

		ELT 16: High active floodplain (n = 59)	ELT 17: Active channel (n = 45)
ELT 15: Stable floodplain (n = 42)	Overstory	$p \le 0.5$	$p \le 0.01$
	Understory	$p \le 0.01$	$p \le 0.01$
	Ground flora	$p \le 0.01$	$p \le 0.01$
ELT 16: Active low floodplain (n = 59)	Overstory	-	$p \le 0.01$
	Understory	-	$p \le 0.01$
	Ground Flora	-	$p \le 0.01$

Table 5. Multi-Response Permutation Procedure (MRPP) results of the floristic differences between paired ELT Phases. The MRPP test statistic T was Tau, Kendall's rank correlation coefficient. $p \le 0.05$ identified those ELT Phases with significant floristic differences. ELT Phases 17.1 and 17.2 were not included in the analysis because they are classified by physiognomic rather than compositional differences, and 14.1 was not included in the analysis because of inadequate sample size. OV = overstory stratum. UN = understory stratum.

	ELTP 16.1 High-energy low floodplain (n = 33)	ELTP 16.2 Stable low floodplain (n = 26)	ELTP 15.1 Active high floodplain (n = 17)	ELTP 15.2 Stable high floodplain (n = 25)
Overstory and understory strata				
ELTP 17.3 Tree-shrub Gravel Bar (n = 21)	OV $p \le 0.05$ UN $p \le 0.05$	OV $p \le 0.05$ UN $p \le 0.01$	OV $p = 0.29$ UN $p \le 0.01$	OV $p \le 0.01$ UN $p \le 0.01$
ELTP 16.1 High-energy low floodplain (n = 33)	-	OV $p \le 0.05$ UN $p \le 0.01$	OV $p \le 0.05$ UN $p \le 0.01$	OV $p \le 0.01$ UN $p \le 0.01$
ELTP 16.2 Stable low floodplain (n = 26)	-	-	OV $p \le 0.01$ UN $p \le 0.05$	OV $p \le 0.05$ UN $p \le 0.01$
ELTP 15.1 Active high floodplain (n = 17)	-	-	-	OV $p \le 0.01$ UN $p = 0.37$
Ground flora stratum				
ELTP 17.3 Tree-shrub Gravel Bar (n = 21)	$p \le 0.01$	$p \le 0.01$	$p \le 0.01$	$p \le 0.01$
ELTP 16.1 High-energy low floodplain (n = 33)	-	$p = 0.06$	$p \le 0.05$	$p \le 0.01$
ELTP 16.2 Stable low floodplain (n = 26)	-	-	$p \le 0.05$	$p \le 0.01$
ELTP 15.1 Active high floodplain (n = 17)	-	-	-	$p = 0.82$

Ground Flora Species Groups

Within the ground flora were species common to all habitats, species of narrow amplitude, and species of low occurrence. To capture the ranges of amplitude and fidelity expressed in the ground flora, we pursued the identification of riparian species groups; these were further investigated for their relationships to ELTs and ELTPs. Of the 214 species classified using TWINSPAN, 30 species were identified for their similar distribution patterns and were segregated into four riparian species groups (see Figure 7).

The habitat type separations listed on the TWINSPAN output reflect the division of plots by TWINSPAN into groups that closely matched our ELT designations. Thus, the two-way output allowed for species group distribution patterns to be viewed in the context of ELT designations.

As suggested by the TWINSPAN output, ground flora species groups vary in their amplitude and habitat fidelity (see Figures 8 and 9; Table 6). Of the four groups identified, two groups are characteristic of specific habitat conditions within a riparian system. Limited in distribution, the *Justicia* species group is present specifically on phases of the Active Channel ELT, habitats that experience intense flooding and inundation. This species group includes sycamore, willow, and river birch seedlings and species commonly seen at the river's edge, such as *Justicia americana*, *Diodea teres*, and *Lippia lanceolata*. At the other extreme is the *Osmorrhiza* species group. Within the riparian landscape, this species group is limited to the Terrace ELT and the Stable High Floodplain ELT. Within a broader context, these species are characteristic of rich mesic upland habitats, such as protected lower slopes, footslopes, and upland waterways (specifically in the Current River Breaks and Jacks Fork-Eleven Point Breaks Landtype Associations). This group includes *Asarum canadense, Osmorrhyza longistylis*, and *Desmodium pauciflorum*, *Carex blanda*, and *Carya cordiformis* seedlings.

Conversely, both the *Lindera* species group and the *Laportea* species group are composed of species present throughout the riparian environment. One reason for the overlap in species distribution is the variety of microhabitats created by the scouring and depositional action of floods. For example, similar microhabitats formed under extremely different circumstances are found on an Active Low Floodplain ELT, where flooding can be either depositional or erosional, and on a Stable Floodplain ELT, where the surface retains the

Figure 7. Simplified TWINSPAN output of the ground flora analysis. Displayed are the 30 species that comprise the riparian species groups. The values listed reflect % cover values, with 1 = rare, 2 = 5% cover, 3 = 10% cover, 4 = 20% cover, 5 = 40% cover, 6 = 65% cover, and 7 = 90% cover.
* Species code names and associated information is found in Appendix B.

```
asarcana* 3322223222-2-2-3-3322-----2----2---------2----------------2-----------------------------------------
carycord  22222-2-222-----------------22------------2----2----------------------------------------------------
desmpauc  3322--2-22-2-------------------------23-----------------------------------------------2-------------   Osmorrhiza
careblan  --3--22223-2322-3222----3222---3----232-----2--2---2-------------------------------2----------------   species group
osmolong  3-3222---2-2-22---23------32222--2--232-------22-2--2-------------2---------------------------------

sanigreg  -222-33--2-2-3233-32-2--3-34222-244---5-2------2--------4--2-----3----3-----------2-----------------
carejame  2323244333-32---3----3-2232323344222243322342-2334344-----2----2222----2----------------------------
festobtu  2-2-434342-42433333--2-2223--2-543242232322-2233-3---223-----3-322--2-2-----------2222--------------
crypcana  -2---3222-22222---2-22-33234--22223422222-2--------2----5434--32222-3-4--32--2--2-2------22---------
asimtril  323223323323-442433323232-2422-22--2-3---3-3-2333422222---------------------------2-----------------   Lindera
violstri  23323432232334344244-22242243343454224342344334224222-224-3--3--323---322-2--2---23------22---------   species group
geumcana  2-2-2222222-24333322-2-22-222222-222-22-2---2-22-----2--2--2----------2-2---------2-2----32----2----
careamph  22--22233-222-2-22--22222223422323223--3232-234333233-332222-322222-22222----2---2--------22--2---22
lindbenz  232322232244233-232-22232-2-22322--22-2--32-223222222-2-2-2-----232---222-22-2-2-2222----2-2-2---2--
polyvirg  2222-22222-222222-22333322442223222332324-22332322-323233-2-2-22--23-222422--5-2322-2-2-222---------

lapocana  -32-332474263453424365434666334465674656445643223333255664446667555454633-42-24253364844433----2-222
elymvirg  ------2-22-23355427523--554544435444-52426563685665456763-33-466355533324----3-3--334--233-5-32---2--
verbalte  ----24333234233343333433324423333-3---3234323633234436444---3332354-32243-3-2332342633-333322--2-222
acernegu  2222-2-223232-23322222-222222--222-2-22-2222222222-2222-22--22222--2--22223222222-2422-2223-2-2222-2   Laportea
uniolati  -------2--2-334464-433232323---2--232---3----3-332-2-23322-2-333-2-322333333333325-24-34444432332322
rudblaci  ------2--32-2323223-33-33334222223322223-2332322----53634334354233434323342426332452333333333-22-2-2   species group
leervirg  -------2--2--32-----322222-2---2--222---323--32322222--333--22332333-222-3323353242-32442---32332---
astelate  ---------------22--22---2--2---2---2----2-------------2-2--2-------2--2--42-2-32223---2423-33-33----

isanbrac  ----------------------------------------------------------------------------------------------------
diodtere  -----------------------------------------------------------------------------------------2--2------2
betunigr  ---------------------------------------------------------------------------------------2---2-33-----
justamer  --------------------------------------------------------------------------------------------4-2-----   Justicia species group
lipplanc  --------------------------------------------------------------------------------------------2-3-----
platocci  -------------------------------------------------------------------------------------2-----222222--2
salicaro  --------------------------------------------------------------------------------------------2-2-2---

          Terraces
                Stable (high) floodplains
                                          Active low floodplains
                                                                                       Active channels
```

Figure 7 (continued)

```
asarcana  --------------------------------------------------

carycord  --------------------------------------------------     Osmorriza species group
desmpauc  --------------------------------------------------
careblan  --------------2-----------------------------------
osmolong  --------------------------------------------------

sanigreg  --------------------------------------------------
carejame  --------------------------------------------------
festobtu  ------------2-------------------------------------
crypcana  --------------------------------------------------
asimtril  --------------------------------------------------
violstri  --------------------------------------------------

geumcana  ------------2-2-2---------------------------------   Lindera species group
careamph  ------------2-------------------------------------
lindbenz  --------------------------------------------------
polyvirg  --------------------------------------------------

lapocana  --------------3-----------------------------------
elymvirg  ------2-2---34--2-----24--------------------------
verbalte  2-2-22----2-3-22-------2--------------------------

acernegu  -22-22----2-3232--2----2--------------2-----------     Laportea species group
uniolati  23-223-2--3-7-333-322322-2----2-------3-----------
rudblaci  2222------2---3--------------2-2------2-----------
leervirg  ---2---------2--------------42--------2-----------
astelate  -2----------2-------------------------3-----------

isanbrac  --22-2-2274-----4-2622-4----------------------2---
diodtere  -2--2-324--2---2222-222--5-2-----------2------2-2-
betunigr  ----------------------------33222--2-32--------2--

justamer  --3-----------------------6255666-55544347462233--   Justicia species group
lipplanc  --------------2-2---------3--3-32-5-323----2------
platocci  2--2---2-2------2---------3--2-352-26-2--3--------
salicaro  224222-2-------3--2-22-2----33244-224333-443-4----

          ------------------------------------------------
                        Active Channels
```

microhabitat features associated with past flood events. The resulting mosaic may allow for species with different habitat requirements to establish.

The *Laporea* species group is composed of the forbs *Rudbeckia laciniata, Laportea canadensis*, *Verbesina alternifolia,* and *Aster lateriflorus*, box elder seedlings, and the grasses *Elymus virginica*, *Uniola latifolia* and *Leersia spp.* (*L. oryzoides* and *L. virginiana*), and is the most widely distributed species group. It is characteristic of riparian habitats likely flooded every few years. The *Lindera* species group is composed of the sedges *Carex jamesii* and *Carex amphibola*, the forbs *Polygonum virginianum*, *Geum canadense, Cryptotaenia canadensis,* and *Viola stricta*, and *Lindera benzoin* and *Asimina triloba* seedlings. This group is a common component of the Stable Low Floodplain ELT, but reaches its highest abundance on stable floodplains and terraces. The species comprising the *Lindera* species group are commonly found on the creeks that feed the Current and Jacks Fork Rivers, and the upland waterways in the Current River Breaks and Jacks Fork Eleven Point Breaks Landtype Association (Nigh et al. In Progress).

Figure 8. Distribution of riparian species groups among Ecological Landtypes (ELT).

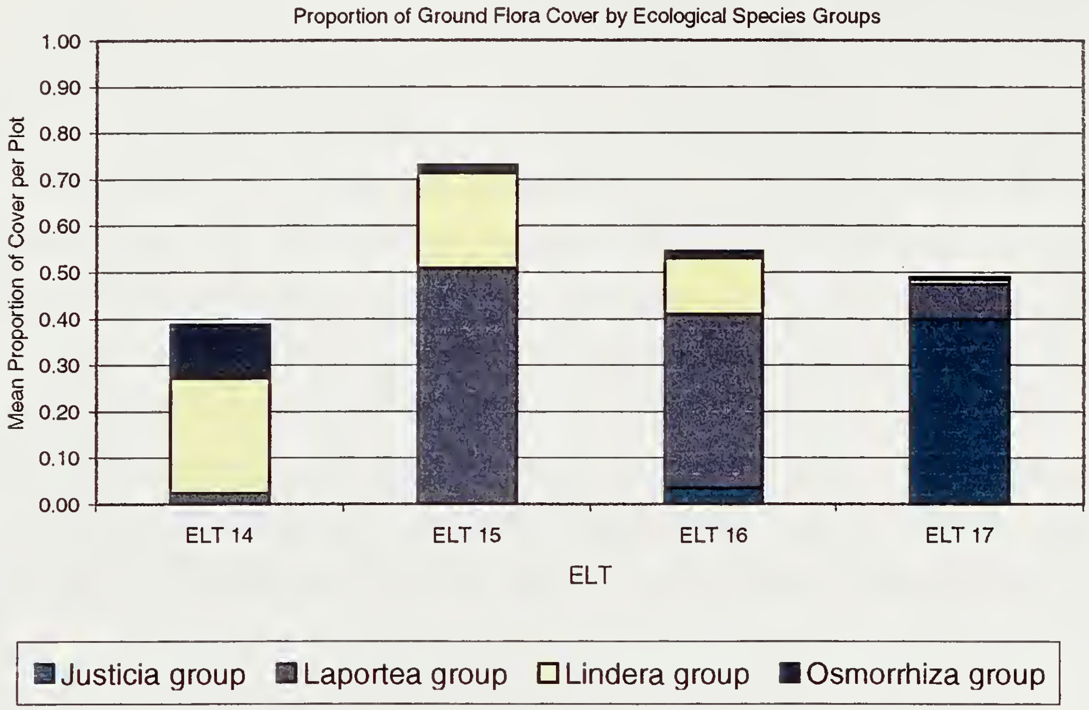


Figure 9. Distribution of ground flora species groups among Ecological Landtype Phases (ELTPs).

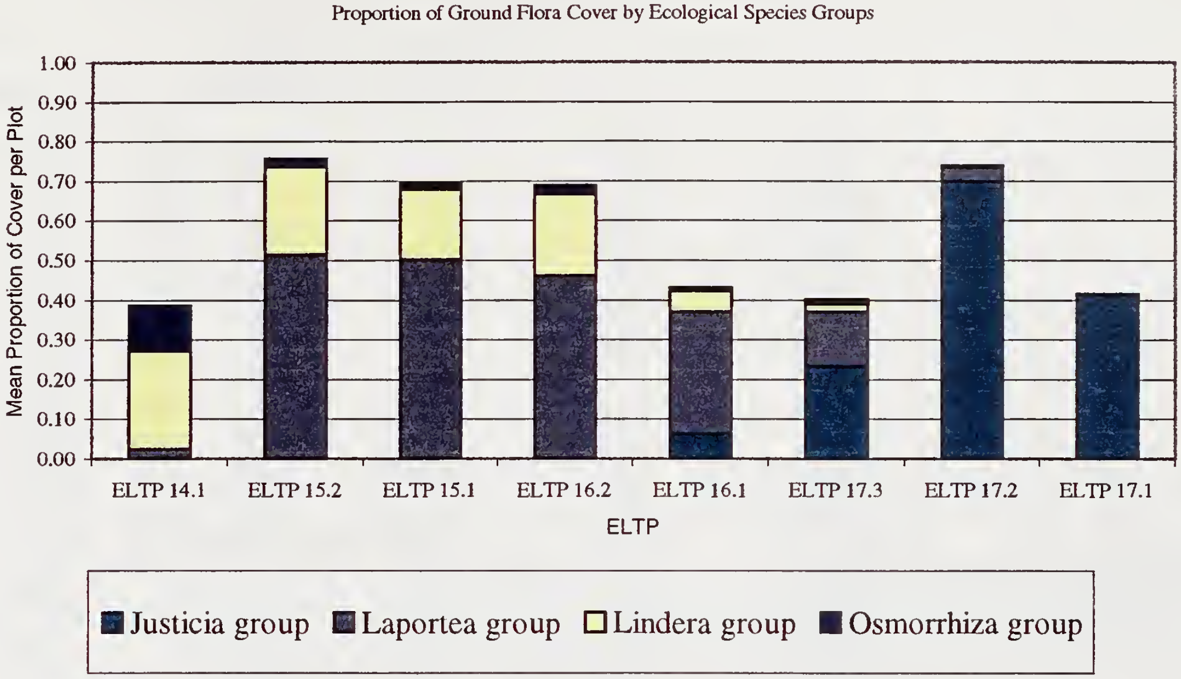
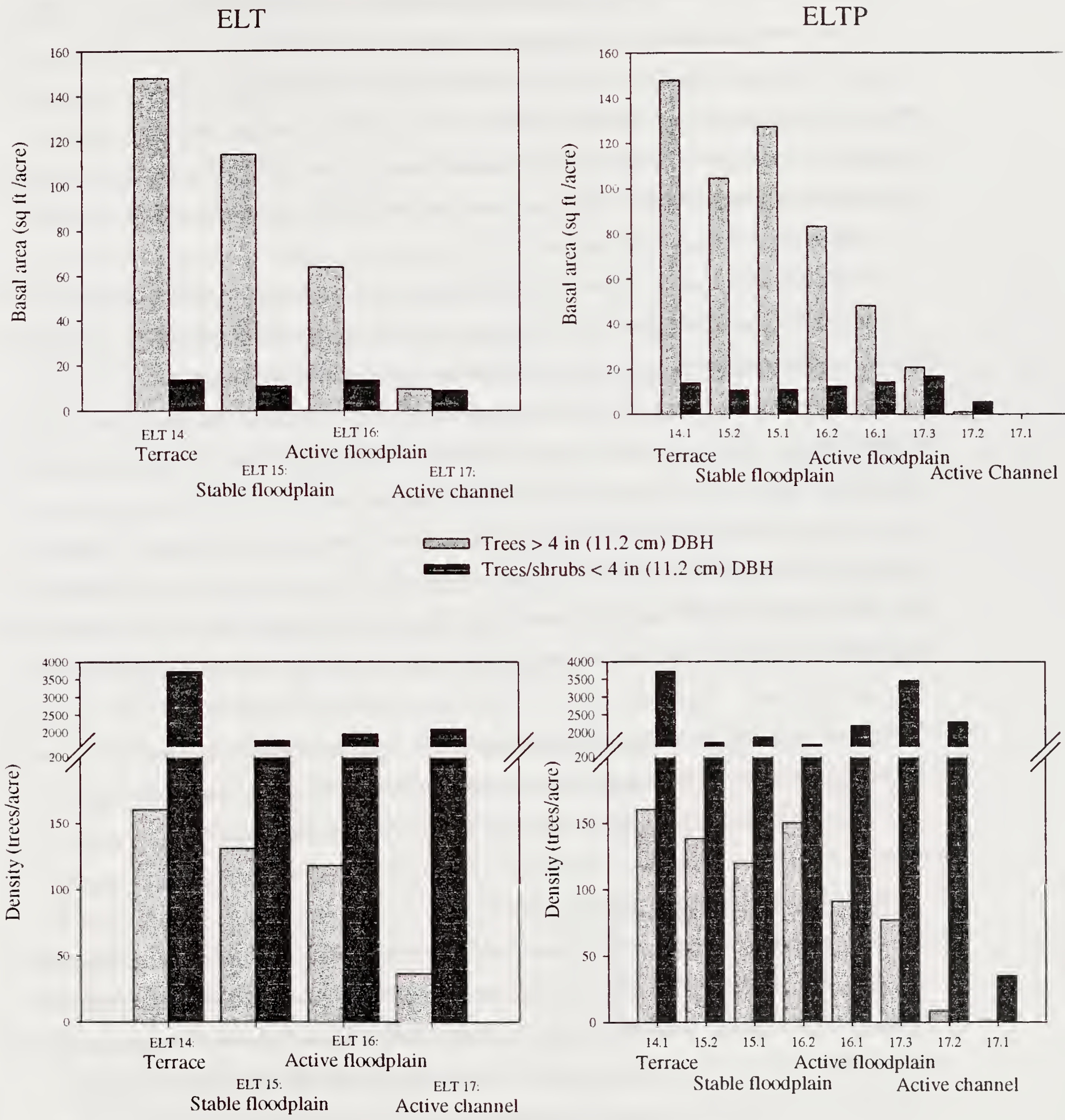


Table 6. Riparian species group distribution among Ecological Landtypes (ELT). The % frequency across ELTs of the species comprising each species group is shown. Species present in greater than 60 % of the plots within an ELT are highlighted in bold. Species code names and associated information are found in Appendix B.

	Species code	Terrace ELT	Stable High Floodplain ELT	Active Low Floodplain ELT	Active Channel ELT
Osmorrhiza species group	asarcana	**1.00**	0.43	0.25	0.00
	carycord	**1.00**	0.50	0.20	0.02
	desmpauc	**1.00**	0.12	0.08	0.02
	careblan	**1.00**	0.55	0.35	0.11
	osmolong	**1.00**	**0.62**	0.20	0.02
Lindera species group	sanigreg	**0.75**	0.45	0.33	0.02
	carejame	**1.00**	**0.83**	0.28	0.02
	festobtu	**0.75**	**0.76**	0.43	0.13
	crypcana	0.50	**0.67**	0.52	0.19
	asimtril	**1.00**	**0.81**	0.47	0.04
	violstri	**1.00**	**0.90**	0.52	0.04
	geumcana	**1.00**	**0.64**	**0.58**	0.15
	careamph	**0.75**	**0.93**	**0.63**	0.15
	lindbenz	**1.00**	**0.93**	**0.65**	0.21
	polyvirg	**1.00**	**0.93**	**0.67**	0.15
Laportea species group	lapocana	**1.00**	**1.00**	**0.80**	0.30
	elymvirg	**0.00**	**0.95**	**0.83**	0.28
	verbalte	**0.75**	**0.98**	**0.85**	0.34
	acernegu	**1.00**	**0.93**	**0.85**	0.38
	chaslati	0.25	0.57	**0.87**	0.57
	rudblaci	0.25	**0.88**	**0.85**	0.34
	leervirg	0.25	**0.74**	**0.72**	0.28
	astelate	0.00	0.31	**0.63**	0.26
Justicia species group	isanbrac	0.00	0.00	0.17	0.17
	diodtere	0.00	0.00	0.17	0.43
	betunigr	0.00	0.00	0.20	0.30
	justamer	0.00	0.00	0.15	**0.55**
	lipplanc	0.00	0.00	0.13	0.32
	platocci	0.00	0.02	0.32	**0.51**
	salicaro	0.00	0.00	0.22	**1.00**

Woody Species Structure. Tree and sapling structure differed among ELTs and ELTPs as well, implying the successional development of a larger tree-dominated system from Active Channel ELTs to Terraces (see Figure 10). Active channels and the active floodplains, positions maintained by frequent flooding, were characterized by a dense pole-sized understory and scattered large trees. In contrast, the stable floodplains and terraces were positions where less frequent flooding allows the development of an overstory of larger trees. The higher basal area was related not only to greater density of overstory trees but also to an increase in larger, established individuals. Sapling density did not differ substantially among the units, but as shown below, composition varied considerably.

Figure 10. Mean basal area (sq ft /acre) and density (trees/acre) by ELT and ELTP.
To convert values from English to metric units, multiply basal area values by 0.229 to derive m^2/ha and density values by 0.405 to derive # trees/ha.



Woody Species Successional Relationships. To further investigate compositional differences, the common woody species were grouped into four types reflecting their distribution along the successional gradient identified by Steyermark (1940) and Witherspoon (1971) (see Figure 11). The Active Channel ELTPs are dominated by smaller-stemmed, early successional Type I and II species. In the first two Phases (17.1 and 17.2), small stemmed river birch, willows, and sycamore dominate, and in the transitional phase (17.3), these species are replaced by box elder and silver maple. Elms, green ash and hackberry saplings, as well as sycamore trees, emerge in the transition phase.

The Active Low Floodplain ELTPs maintain some Type I and II species and recruit mid-successional Type III species. In the transition phase (16.1), a strong sapling and sub-canopy of American elm, green ash, and hackberry is present, which distinguishes it from the transition phase of the Active Channel (17.3). These species begin to emerge as trees in the more stable Active Floodplain phase (16.2). Sycamore saplings are largely replaced by box elder, hackberry, and elm in Phase 16.2. Sugar maple occurs in the sapling layer in 16.2 as well.

The Stable Floodplain and Terrace ELTPs recruit later sucessional Type IV species. Having lost the sycamore and willow sapling component in the understory, the understories of Stable Floodplain ELTPs are dominated by box elder, elm, and hackberry and, to a lesser extent, pawpaw and spicebush. In the overstory, sycamore and box elder share dominance with elm, ash, and hackberry. Phases 15.1 and 15.2 differ in the degree of transition to dominance by Type IV species (sugar maple, oaks, and bitternut hickory). Terraces have an elm, hackberry, pawpaw and spicebush understory component, with sugar maple increasing in abundance and an overstory characterized by oaks, sugar maple, and bitternut hickory.

SUMMARY AND CONCLUSIONS

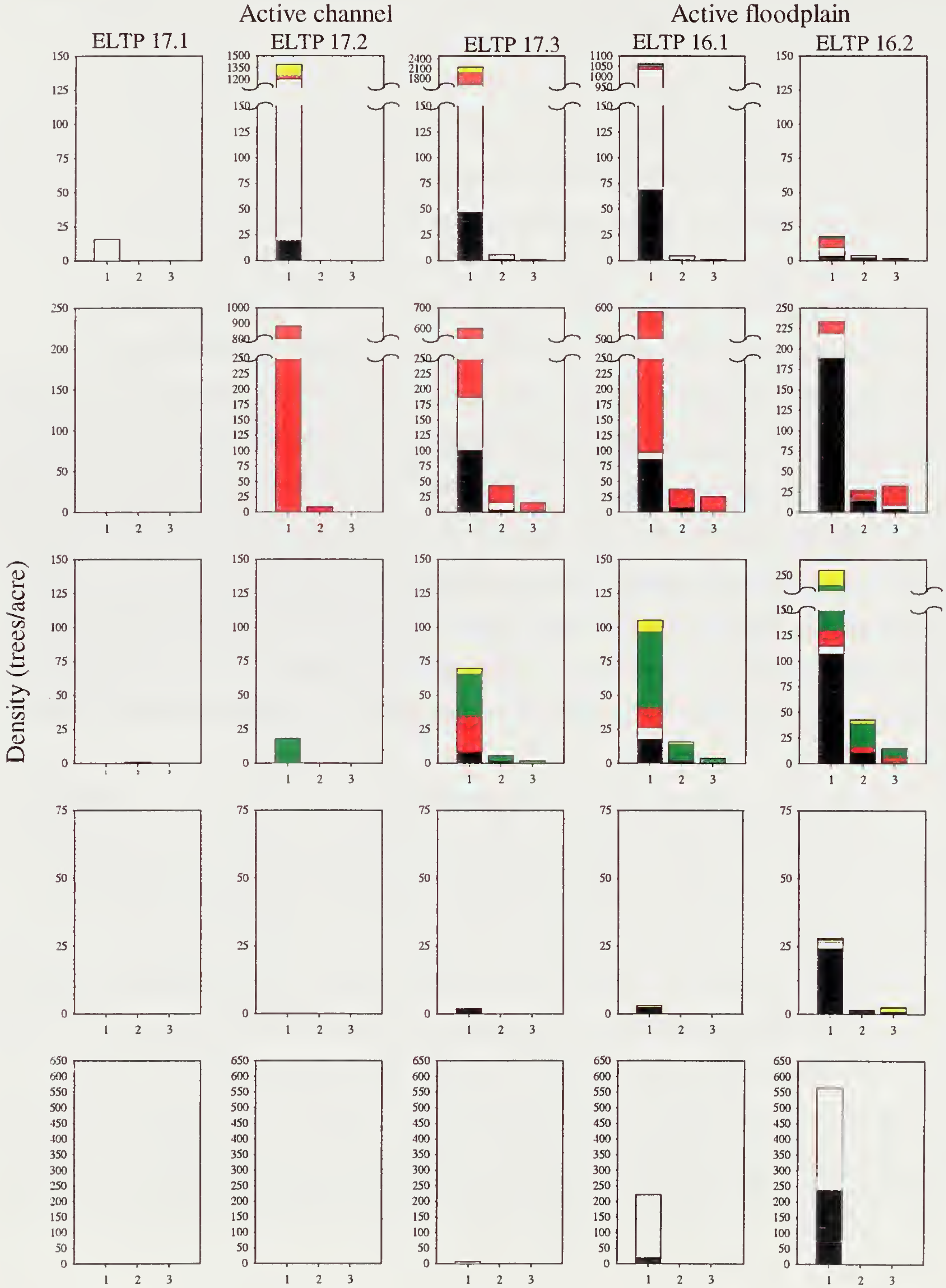
Riparian ecosystems are composed of a complex suite of interdependent environmental factors interacting with vegetation through time. Flood events vary widely in their frequency, intensity, and duration, creating a dynamic system within a watershed or a stream reach. Despite the complex nature of these systems, strong relationships between vegetation and physical factors of the riparian environment are present.

Ecological classification, like classification of any kind, is an artificial construct that attempts to categorize and classify things. A walk through a bottomland forest reinforces the notion that shifts in vegetation distribution are rarely abrupt and dramatic. However, this study has shown that fluvial landforms tend to have certain physical properties that are strongly related to vegetation. Fluvial landforms, such as active channels, active low floodplains, stable floodplains, and terraces, are identifiable zones with characteristic locations, elevations, shapes, parent materials, and soil properties that are related to flood regimes. Vegetation development in riparian areas is a function of time and the physical properties of the fluvial landform on which development progresses. The direct relationship between landform-associated physical properties and vegetation pattern make fluvial landforms a viable structure for describing riparian ecosystems. Our ELT and ELTP classification is built upon this relationship.

Active Channels (ELT 17) are characterized by low elevation and proximity to the river where frequent floods occur. Because of this position, they are largely an erosional surface where fine substrate materials tend to be removed and coarse materials such as gravel and sand are shifting around. Most of these surfaces are less than 20 years old (T_0/T_1 after Albertson et al.1995). Vegetation development is limited by frequent flooding, and consequently, species adapted to pioneering, such as willows and sycamores are dominant. Phases within this ELT, gravel bars (17.1 and 17.2) and young, early successional forests of newly deposited thin sand (17.3), are largely related to the accumulation of vegetation and young soil materials through time.

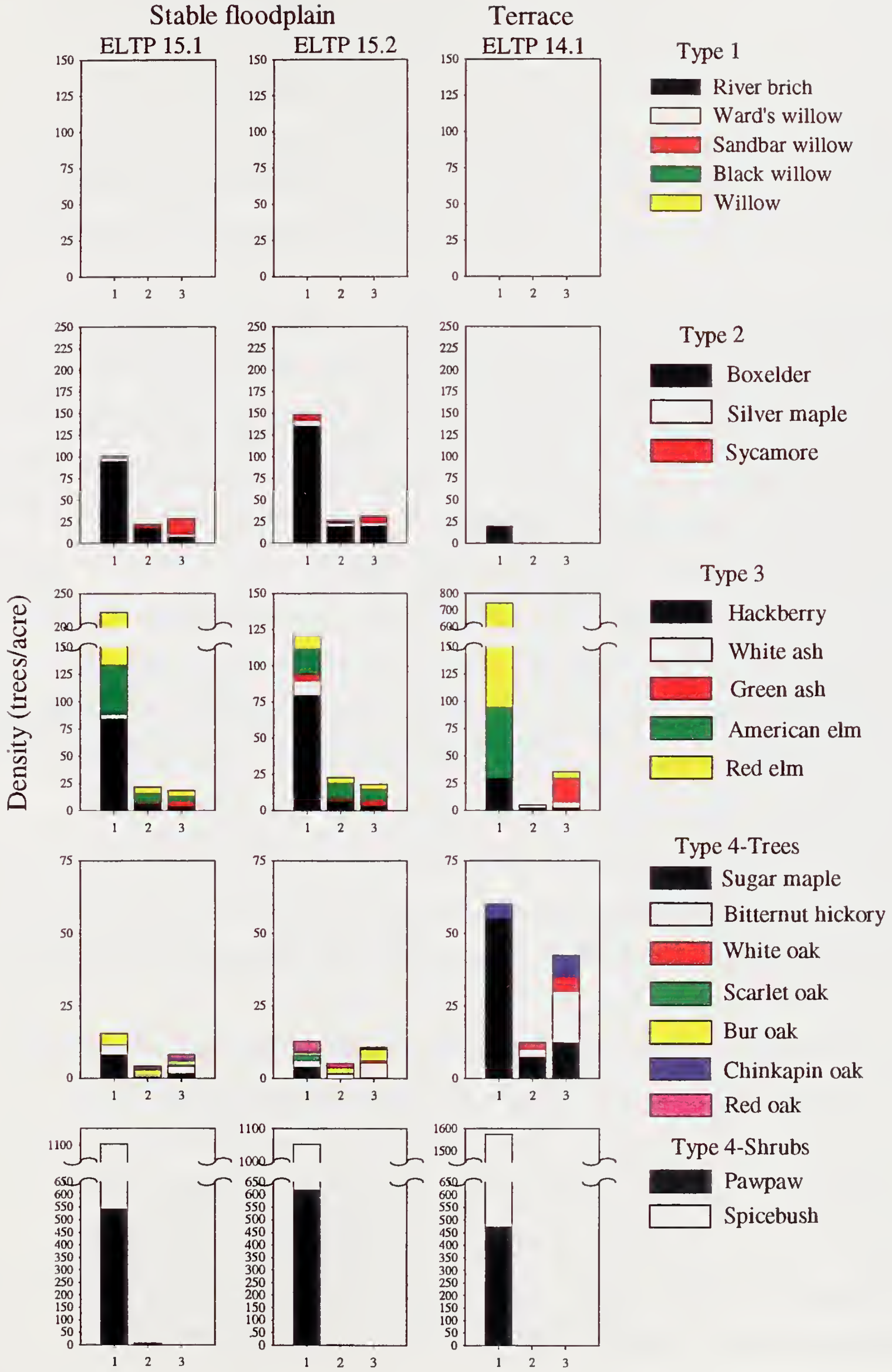
Active Low Floodplains (ELT 16) are slightly elevated, 6 to 15 ft (2 to 5 m) above Active Channels (ELT 17). Consequently, they receive several seasonal floods each year and are in a position where scouring and deposition of sandy soil materials are frequent. Distinctions between ELT Phases are related to degree of flooding and vegetation development. They may have evolved from gravel bars as sandy soil materials and vegetation accumulated (16.1) or, less frequently, when high floodplains were degraded in an unusual peak flood event (16.2). These surfaces are generally 10s to 100s of years old (T_1/T_2 after Albertson et al. 1995). Soil development is minimal, being restricted mainly to the accumulation of organic matter; the soils often show multiple bands of former surfaces. Vegetation includes former gravel bar species, such as sycamore, along with species such as American elm, green ash, hackberry, and nettles

Figure 11. Distribution of woody species within successional groups (Witherspoon 1971) across ELTPs. Density of overstory and understory species is displayed by diameter class. To convert values from ft^2/acres to m^2/ha, multiply values by 0.229.



Diameter classes: 1 = 0 to 4.4 in (0 to 11.2 cm) 2 = 4.5 to 8.4in (11.3 to 21.3 cm)
3 => 8.4 in (21.3cm)

Figure 11. Continued.



Diameter classes: 1 = 0 to 4.4 in (0 to 11.2 cm) 2 = 4.5 to 8.4in (11.3 to 21.3 cm)
3 => 8.4 in (21.3cm)

characteristic of frequently flooded riverfront forests. Most of the uncleared and naturally vegetated bottomlands in OZAR are in this ELT.

Stable Floodplains (ELT 15) are higher, 15 to 30 ft (5 to 10 m), and often more protected from flooding than Active Low Floodplains (ELT 16). ELT Phases (15.1 and 15.2) differ in soil and vegetation development related to timing and intensity of flooding. Ecosystems in ELT 15 are subjected to occasional flooding by the highest seasonal floods, but because of their position, flood disturbance is minimal. Consequently, these ELTs are in more of an accumulating position for fine soil materials. These surfaces are 100s to 1,000s of years old (T_2/T_3 after Albertson et al. 1995). Soils tend to be silty and better developed than in lower positions, with occasional development of an argillic horizon. Vegetation development has proceeded with the addition of less flood-tolerant species such as oaks, sugar maple, bitternut hickory, and pawpaw, as well as numerous mesic upland herbaceous species. Large, uncleared and intact examples of this ELT are uncommon in the park; most were cleared years ago for farming. Most of our plots were in isolated high areas within areas dominated by low floodplains; consequently there may be higher, better-developed examples that are not described by this study.

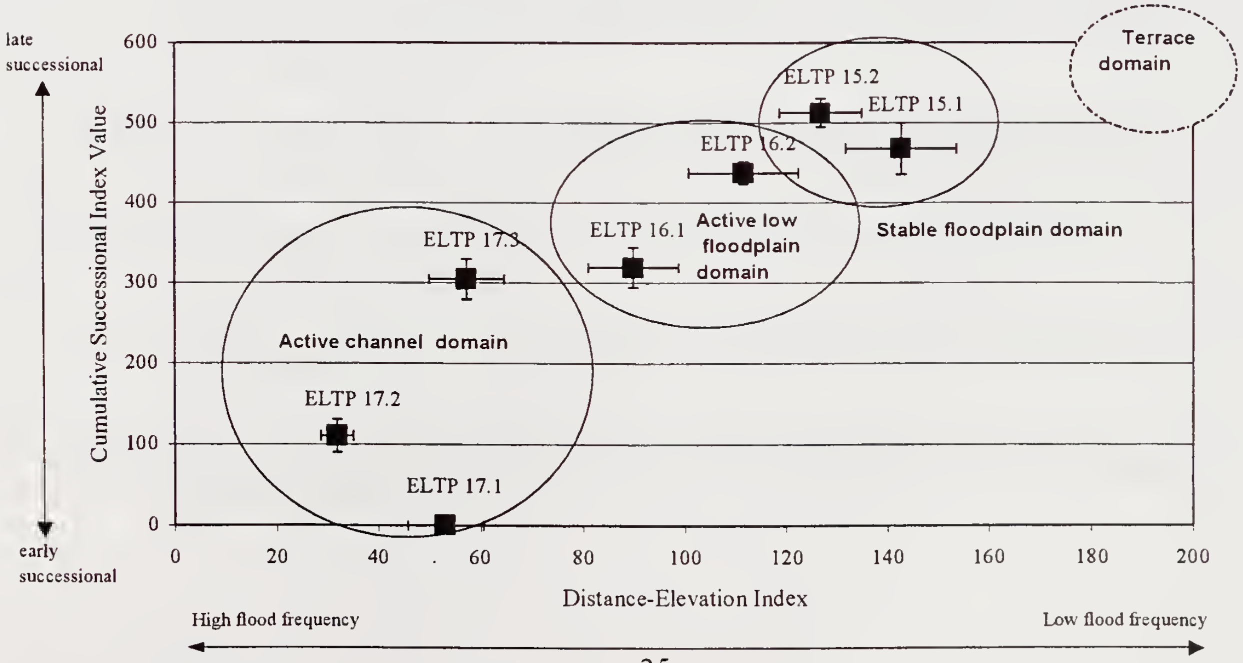
Terraces (ELT 14) are very high, 30 to 80 ft (10 to 25 m) remnants of former floodplains that are only rarely flooded today by the most extreme events. These surfaces are 1,000s to 10,000s of years old (T_4/T_5 after Albertson et al. 1995). They are formed in ancient alluvium and occasional colluvium that has drifted downslope from the uplands. Soils are well-developed loamy and silty alfisols with definite development of an argillic horizon. Vegetation is dominated by flood-intolerant species such as oaks, bitternut hickory, sugar maple, spicebush and mesic forest herbs. Large, uncleared and intact terraces are extremely rare in the park; we found only isolated remnants as most were cleared. Consequently, characterization of these units was limited.

We believe that the four ELTs offer a framework for segregating “Domains” of pattern and process and, consequently, management potential within the riparian zone of the park (Figure 12). We have constructed a conceptual model of riparian ecosystems that is based largely on fluvial landforms and variations in vegetation and environment within them. This model is a simplification of a very complex and shifting set of biophysical land units. Flash-flood events and shifting river channels together create an ecosystem that goes through periodic pulses of change along with lengthy periods of relative stability. Forest heterogeneity is maintained by this erosional-depositional character of the river, with the riverside landscape a mosaic of communities able to withstand different levels of flood disturbance.

Each ELT domain has an overall set of characteristics largely dictated by its flood regimes. Most changes in pattern and process occur within domains (between ELTPs within an ELT), are gradual, and take place during periods of relative stability. Change from one domain (ELT) to another will occur in the long term, given an extreme flood event that disturbs both the physical properties and vegetation community structure and composition. As one moves from Active Channels to Terraces, time periods of change both within and between domains likely increases.

Within each ELT domain, the degree of change differs, depending on the vulnerability of the ELT domain to both abrupt and gradual changes in river patterns. Given the proximity to the river's edge, the Active Channel is a domain of dynamic change. Although 17.3 and 16.1 are similar in their vegetation successional stage (see Figure 12), 17.3 is in a position where flooding disturbance can be severe enough to uproot trees and either remove the upper soil horizon or bury it under new deposition. The coarse, gravelly, frequently shifting substrates and annual flood disturbance provide limited time for vegetation establishment.

Fig. 12. Conceptual model of ELT domains. The CSI values were derived from woody data as desribed in the methods. The Distance-Elevation Index is a measure of combined relative elevation and distance; it strings plots from low and close Active Channels to high and distant High Floodplains. Terraces not included in model due to low sample size.



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APPENDIX A.
Woody species encountered during sampling.

Family	Scientific Name	Common Name	Species Code
Aceraceae	*Acer negundo*	box elder	acernegu
	Acer saccharinum	silver maple	acersaci
	Acer saccharum	sugar maple	acersacu
Anacardiaceae	*Rhus glabra*	smooth sumac	rhusglab
	Toxicodendron radicans	poison ivy	toxiradi
Annonaceae	*Asimina triloba*	pawpaw	asimtril
Aristolochiaceae	*Aristolochia tomentosa*	pipe-vine	aristome
Betulaceae	*Betula nigra*	river birch	betunigr
	Carpinus caroliniana ssp. caroliniana	hornbeam	carpcaro
	Corylus americana var. indehiscens	hazelnut	coryamer
	Ostrya virginiana	hop hornbeam	ostrvirg
Bignoniaceae	*Campsis radicans*	trumpet creeper	campradi
	Catalpa speciosa.	catalpa	cataspec
Caprifoliaceae	*Sambucus canadensis*	elderberry	sambcana
	Symphoricarpos orbiculatus	coralberry	symporbi
	Viburnum rufidulum	southern black haw	viburufi
Celastraceae	*Euonymus atropurpurea*	wahoo	euonatro
Cornaceae	*Cornus drummondii*	rough-leaved dogwood	corndrum
	Cornus florida	flowering dogwood	cornflor
Cupressaceae	*Juniperus virginiana*	red cedar	junivirg
Ebenaceae	*Diospyros virginiana*	persimmon	diosvirg
Fagaceae	*Quercus alba*	white oak	queralba
	Quercus coccinea	scarlet oak	quercocc
	Quercus macrocarpa	bur oak	quermacr
	Quercus muhlenbergii	chinquapin oak	quermuhl
	Quercus rubra	red oak	querrubr
Hamamelidaceae	*Hamamelis vernalis*	vernal witch hazel	hamavern
Hippocastanaceae	*Aesculus glabra var. arguta*	Ohio buckeye	aescglab
Juglandaceae	*Carya cordiformis*	bitternut hickory	carycord
	Carya laciniosa	shellbark hickory	carylaci
	Carya tomentosa	mockernut hickory	carytome
	Juglans cinerea	butternut	juglcine
	Juglans nigra	black walnut	juglnigr
Lauraceae	*Lindera benzoin*	spicebush	lindbenz
	Sassafras albidum	sassafras	sassalbi
Leguminosae	*Amorpha fruticosa*	false indigo	amorfrut
	Cercis canadensis	redbud	cerccana
	Gleditsia triacanthos	honey locust	gledtria

APPENDIX B.

Taxonomic identification, physiognomy, and species code for ground flora species encountered. Scientific names of exotic species are capitalized.

Family	Scientific Name	Common Name	Physiognomy	Species Code
Acanthaceae	*Dicliptera brachiata*	wild mudwort	Nt A-FORB	diclbrac
	Justicia americana	water willow	Nt P-FORB	justamer
	Ruellia strepens	smooth ruellia	Nt P-FORB	ruelstre
Aceraceae	*Acer negundo*	box elder	Nt TREE	acernegu
	Acer saccharinum	silver maple	Nt TREE	acersaci
	Acer saccharum	sugar maple	Nt TREE	acersacu
Aizoaceae	MOLLUGO VERTICILLATA	carpet weed	Ad A-FORB	mollvert
Alismaceae	*Alisma plantago-aquatica*	water plantain	Nt P-FORB	alisplan
	Sagittaria latifolia	common arrowhead	Nt P-FORB	sagilati
Amaranthaceae	AMARANTHUS HYBRIDUS	green amaranth	Ad A-FORB	amarhybr
	Amaranthus tamariscinus	water hemp	Nt A-FORB	amartama
	Froelichia floridana	large cottonweed	Nt A-FORB	froeflor
	Froelichia gracilis	small cottonweed	Nt A-FORB	froegrac
	Iresine rhizomatosa	bloodleaf	Nt P-FORB	iresrhiz
Anacardiaceae	*Rhus copallina latifolia*	shining sumac	Nt SHRUB	rhuscopa
	Rhus glabra	smooth sumac	Nt SHRUB	rhusglab
	Toxicodendron radicans	poison ivy	Nt W-VINE	toxiradi
Annonaceae	*Asimina triloba*	pawpaw	Nt TREE	asimtril
Apiaceae	*Cicuta maculata*	water hemlock	Nt B-FORB	cicumacu
	Cryptotaenia canadensis	honewort	Nt P-FORB	crypcana
	DAUCUS CAROTA	Queen Anne's lace	Ad B-FORB	dauccaro
	Ligusticum canadense	angelico	Nt P-FORB	ligucana
	Osmorhiza longistylis	smooth sweet cicely	Nt P-FORB	osmolong
	Oxypolis rigidior	cowbane	Nt P-FORB	oxyprigi
	Sanicula canadensis	Canadian black snakeroot	Nt B-FORB	sanicana
	Sanicula gregaria	clustered black snakeroot	Nt P-FORB	sanigreg
	Taenidia integerrima	yellow pimpernel	Nt P-FORB	taeninte
	Thaspium barbinode	hairy meadow parsnip	Nt P-FORB	thasbarb
	Thaspium trifoliatum	meadow parsnip	Nt P-FORB	thastrif
	Zizia aptera	heart-leaved meadow parsnip	Nt P-FORB	ziziapte
	Zizia aurea	golden alexanders	Nt P-FORB	ziziaure
Apocynaceae	*Amsonia illustris*	shining blue star	Nt P-FORB	amsoillu
Araceae	*Arisaema atrorubens*	Jack-in-the pulpit	Nt P-FORB	arisatro
	Arisaema dracontium	green dragon	Nt P-FORB	arisdrac
	Peltandra virginica	arrow arum	Nt P-FORB	peltvirg
Araliaceae	*Panax quinquefolius*	ginseng	Nt P-FORB	panaquin
Aristolochiaceae	*Aristolochia tomentosa*	pipe-vine	Nt W-VINE	aristome
	Asarum canadense	wild ginger	Nt P-FORB	asarcana

Family	Scientific Name	Common Name	Physiognomy	Species Code
Asteraceae	*Rudbeckia fulgida*	orange coneflower	Nt P-FORB	rudbfulg
	Rudbeckia hirta	black-eyed Susan	Nt P-FORB	rudbhirt
	Rudbeckia laciniata	wild golden glow	Nt P-FORB	rudblaci
	Rudbeckia triloba	brown-eyed susan	Nt B-FORB	rudbtril
	Senecio obovatus	round-leaved ragwort	Nt P-FORB	seneobov
	Silphium perfoliatum	cup plant	Nt P-FORB	silpperf
	Solidago altissima	tall goldenrod	Nt P-FORB	solialti
	Solidago arguta	sharp-leaved goldenrod	Nt P-FORB	soliargu
	Solidago caesia	blue-stemmed goldenrod	Nt P-FORB	solicaes
	Solidago flexicaulis	broad-leaved goldenrod	Nt P-FORB	soliflex
	Solidago gigantea	late goldenrod	Nt P-FORB	soligiga
	Solidago nemoralis	old-field goldenrod	Nt P-FORB	solinemo
	Solidago ulmifolia	elm-leaved goldenrod	Nt P-FORB	soliulmi
	TARAXACUM OFFICINALE	common dandelion	Ad P-FORB	taraoffi
	Verbesina alternifolia	yellow ironweed	Nt P-FORB	verbalte
	Verbesina virginica	white crownbeard	Nt P-FORB	verbvirg
	Vernonia baldwini	western ironweed	Nt P-FORB	vernbald
	Vernonia crinita	great ironweed	Nt P-FORB	verncrin
	XANTHIUM STRUMARIUM	cocklebur	Ad A-FORB	xantstru
Balsaminaceae	*Impatiens capensis*	orange jewelweed	Nt A-FORB	impacape
	Impatiens spp.	jewelweed	Nt A-FORB	impatspp
Berberidaceae	*Podophyllum peltatum*	May apple	Nt P-FORB	podopelt
Bignoniaceae	*Campsis radicans*	trumpet creeper	Nt W-VINE	campradi
Boraginaceae	ECHIUM VULGARE	viper's bugloss	Ad B-FORB	echivulg
	Lithospermum canescens	hoary puccoon	Nt P-FORB	lithcane
Campanulaceae	*Campanula americana*	tall bellflower	Nt A-FORB	campamer
	Lobelia cardinalis	cardinal flower	Nt P-FORB	lobecard
	Lobelia siphilitica	great blue lobelia	Nt P-FORB	lobesiph
	Specularia perfoliata	perfoliate Venus' looking glass	Nt A-FORB	specperf
Capparidaceae	*Polanisia dodecandra*	clammyweed	Nt A-FORB	poladode
Caprifoliaceae	*Lonicera flava*	yellow honeysuckle	Nt W-VINE	loniflav
	Sambucus canadensis	elderberry	Nt SHRUB	sambcana
	Symphoricarpos orbiculatus	coralberry	Nt SHRUB	symporbi
	Triosteum angustifolium	yellow-flowered horse gentian	Nt P-FORB	trioangu
	Triosteum aurantiacum	early horse gentian	Nt P-FORB	trioaura
	Viburnum rufidulum	southern black haw	Nt SHRUB	viburufi
Caryophyllaceae	SAPONARIA OFFICINALIS	bouncing bet	Ad P-FORB	sapooffi
	Silene stellata	starry campion	Nt P-FORB	silestel
	Silene virginica	fire pink	Nt P-FORB	silevirg
	STELLARIA MEDIA	common chickweed	Ad A-FORB	stelmedi
Celastraceae	*Euonymus atropurpureus*	wahoo	Nt SHRUB	euonatro
Chenopodiaceae	CHENOPODIUM ALBUM	lamb's quarters	Ad A-FORB	chenalbu
	CHENOPODIUM AMBROSIOIDES	Mexican tea	Ad A-FORB	chenambr
	Chenopodium standleyanum	woodland goosefoot	Nt A-FORB	chenstan

Family	Scientific Name	Common Name	Physiognomy	Species Code
Dioscoreaceae	*Dioscorea quaternata*	four-leaf yam	Nt H-VINE	diosquat
	Dioscorea villosa	wild yam	Nt H-VINE	diosvill
Ebenaceae	*Diospyros virginiana*	persimmon	Nt TREE	diosvirg
Equisetaceae	*Equisetum arvense*	horsetail	Nt FERN	equiarve
Euphorbiaceae	*Acalypha gracilens*	slender mercury	Nt A-FORB	acalgrac
	Acalypha rhomboidea	rhombic copperleaf	Nt A-FORB	acalrhom
	Acalypha virginica	Virginia mercury	Nt A-FORB	acalvirg
	Croton glandulosus	sand croton	Nt A-FORB	crotglan
	Croton monanthogynus	prairie tea	Nt A-FORB	crotmona
	Euphorbia dentata	toothed spurge	Nt A-FORB	euphdent
	Euphorbia heterophylla	painted spurge	Nt A-FORB	euphhete
	Euphorbia maculata	nodding spurge	Nt A-FORB	euphmacu
	Euphorbia supina	creeping spurge	Nt A-FORB	euphsupi
Fagaceae	*Quercus alba*	white oak	Nt TREE	queralba
	Quercus coccinea	scarlet oak	Nt TREE	quercocc
	Quercus coccinea/rubra	scarlet/red oak	Nt TREE	quercoru
	Quercus macrocarpa	bur oak	Nt TREE	quermacr
	Quercus muhlenbergii	chinquapin oak	Nt TREE	quermuhl
	Quercus rubra	red oak	Nt TREE	querrubr
	Quercus velutina	black oak	Nt TREE	quervelu
Fumariaceae	*Corydalis flavula*	pale corydalis	Nt B-FORB	coryflav
Geraniaceae	*Geranium maculatum*	wild geranium	Nt P-FORB	geramacu
Haloragidaceae	*Myriophyllum heterophyllum*	various-leaved water milfoil	Nt P-FORB	myrihete
Hamamelidaceae	*Hamamelis vernalis*	vernal witch hazel	Nt SHRUB	hamavern
Hippocastanaceae	*Aesculus glabra*	Ohio buckeye	Nt TREE	aescglab
Hydrophyllaceae	*Ellisia nyctelea*	Aunt Lucy	Nt A-FORB	ellinyct
	Hydrophyllum appendiculatum	great waterleaf	Nt P-FORB	hydrappe
	Hydrophyllum canadense	Canada waterleaf	Nt P-FORB	hydrocan
	Hydrophyllum virginianum	virginia waterleaf	Nt P-FORB	hydrvirg
	Phacelia bipinnatifida	forest phacelia	Nt B-FORB	phacbipi
	Phacelia spp.	Phacelia	Nt A/B-FORB	phacespp
Hypericaceae	*Hypericum punctatum*	Spotted St. John's wort	Nt P-FORB	hypepunc
	Hypericum spathulatum	Shrubby St. John't wort	Nt SHRUB	hypespat
Iridaceae	*Sisyrinchium bermudiana*	pointed blue-eyed grass	Nt P-FORB	sisyberm
Juglandaceae	*Carya cordiformis*	bitternut hickory	Nt TREE	carycord
	Carya tomentosa	mockernut hickory	Nt TREE	carytome
	Juglans nigra	black walnut	Nt TREE	juglnigr
Labiatae	*Agastache nepetoides*	yellow giant hyssop	Nt P-FORB	agasnepe
	Blephilia hirsuta	wood mint	Nt P-FORB	blephirs
	Collinsonia canadensis	richweed	Nt P-FORB	collcana
	Cunila origanoides	dittany	Nt P-FORB	cuniorig
	GLECHOMA HEDERACEA	creeping Charlie	Ad P-FORB	glechede
	Isanthus brachiatus	false pennyroyal	Nt A-FORB	isanbrac
	LAMIUM PURPUREUM	purple dead nettle	Ad P-FORB	lamipurp

Family	Scientific Name	Common Name	Physiognomy	Species Code
Liliaceae	*Smilax tamnoides*	bristly greenbriar	Nt W-VINE	smiltamn
	Trillium sessile	toad trillium	Nt P-FORB	trilsess
	Uvularia grandiflora	bellwort	Nt P-FORB	uvulgran
Lythraceae	*Rotala ramosior*	toothcup	Nt A-FORB	rotaramo
Malvaceae	*Hibiscus lasiocarpos*	rose mallow	Nt P-FORB	hibilasi
	SIDA SPINOSA	prickly sida	Ad A-FORB	sidaspin
Menispermaceae	*Calycocarpum lyoni*	cupseed	Nt W-VINE	calylyon
	Cocculus carolinianus	Carolina snailseed	Nt W-VINE	cocccaro
	Menispermum canadense	moonseed	Nt W-VINE	menicana
Moraceae	*Humulus lupulus*	common hop	Nt H-VINE	humulupu
	Morus rubra	red mulberry	Nt TREE	morurubr
Nyctaginaceae	*Mirabilis nyctaginea*	wild four o'clock	Nt P-FORB	miranyct
Oleaceae	*Fraxinus americana*	white ash	Nt TREE	fraxamer
	Fraxinus pennsylvanica	green ash	Nt TREE	fraxpenn
	Fraxinus quadrangulata	blue ash	Nt TREE	fraxquad
Onagraceae	*Circaea quadrisulcata*	enchanter's nightshade	Nt P-FORB	circquad
	Ludwigia palustris	water purslane	Nt P-FORB	ludwpalu
	Oenothera biennis	common evening primrose	Nt B-FORB	oenobien
	Oenothera missouriensis	Missouri primrose	Nt P-FORB	oenomiss
Ophioglossaceae	*Botrychium dissectum*	cut-leaved grape fern	Nt FERN	botrdiss
	Botrychium virginianum	rattlesnake fern	Nt FERN	botrvirg
Orchidaceae	*Aplectrum hyemale*	putty root orchid	Nt P-FORB	aplehyem
	Liparis liliifolia	purple twayblade	Nt P-FORB	lipalili
	Orchis spectabilis	showy orchis	Nt P-FORB	orchspec
Oxalidaceae	*Oxalis dillenii*	yellow wood sorrel	Nt P-FORB	oxaldill
	Oxalis stricta	common wood sorrel	Nt P-FORB	oxalstri
Papaveraceae	*Sanguinaria canadensis*	bloodroot	Nt P-FORB	sangcana
	Stylophorum diphyllum	celandine poppy	Nt P-FORB	styldiph
Phrymaceae	*Phryma leptostachya*	lopseed	Nt P-FORB	phrylept
Phytolaccaceae	*Phytolacca americana*	pokeweed	Nt P-FORB	phytamer
Plantaginaceae	PLANTAGO LANCEOLATA	English plantain	Ad A-FORB	planlanc
	Plantago rugelii	rugel plantain	Nt A-FORB	planruge
Platanaceae	*Platanus occidentalis*	sycamore	Nt TREE	platocci
Poaceae	*Agrostis hyemalis*	tickle grass	Nt P-GRASS	agrohyem
	Agrostis perennans	upland bent	Nt P-GRASS	agropere
	Andropogon gerardi	big bluestem	Nt P-GRASS	andrgera
	Andropogon scoparius	little bluestem	Nt P-GRASS	andrscop
	Arundinaria gigantea	cane	Nt P-GRASS	arungiga
	Brachyelytrum erectum	long-awned wood grass	Nt P-GRASS	bracerec
	Bromus latiglumis	ear-leaved brome	Nt P-GRASS	bromlati
	Bromus purgans	woodland brome	Nt P-GRASS	brompurg
	BROMUS TECTORUM	downy brome	Ad A-GRASS	bromtect
	Cinna arundinacea	common wood reed	Nt P-GRASS	cinnarun

Family	Scientific Name	Common Name	Physiognomy	Species Code
Polygonaceae	*Polygonum virginianum*	virginia knotweed	Nt P-FORB	polyvirg
	Polygonum spp.	knotweed	Nt P-FORB	polymspp
	Rumex altissimus	pale dock	Nt P-FORB	rumealti
	RUMEX CRISPUS	curly dock	Ad P-FORB	rumecris
Polypodiaceae	*Cystopteris fragilis*	fragile fern	Nt FERN	cystfrag
	Thelypteris hexaganaptera	broad beech fern	Nt FERN	thelhexa
	Woodsia obtusa	cliff fern	Nt FERN	woodobtu
Pontederiaceae	*Heteranthera dubia*	water star-grass	Nt P-FORB	hetedubi
Primulaceae	*Lysimachia ciliata*	fringed loosestrife	Nt P-FORB	lysicili
	Lysimachia lancealata	lance-leaved loosestrife	Nt P-FORB	lysilanc
	LYSIMACHIA NUMMULARIA	moneywort	Ad P-FORB	lysinumm
Ranunculaceae	*Anemane virginiana*	tall anemone	Nt P-FORB	anemvirg
	Anemanella thalictraides	rue anemone	Nt P-FORB	anemthal
	Clematis pitcheri	leather flower	Nt W-VINE	clempitc
	Clematis virginiana	virgin's bower	Nt W-VINE	clemvirg
	Hepatica nabilis v. abtusa	round-lobed hepatica	Nt P-FORB	hepanobi
	Hydrastis canadensis	golden seal	Nt P-FORB	hydracan
	Ranunculus abartivus	small-flowered buttercup	Nt P-FORB	ranuabor
	Ranunculus recurvatus	hooked buttercup	Nt P-FORB	ranurecu
	Ranunculus septentrionalis	swamp buttercup	Nt P-FORB	ranusept
	Ranunculus spp.	buttercup	Nt P-FORB	ranunspp
	Thalictrum revalutum	waxy meadow rue	Nt P-FORB	thalrevo
Rhamnaceae	*Rhamnus caraliniana*	Carolina buckthorn	Nt SHRUB	rhamcaro
Rosaceae	*Agrimania pubescens*	soft agrimony	Nt P-FORB	agripube
	Agrimania rastellata	beaked agrimony	Nt P-FORB	agrirost
	Crataegus spp.	hawthorn	Nt TREE	crataspp
	Geum canadense	white avens	Nt P-FORB	geumcana
	Physacarpus apulifolius	ninebark	Nt SHRUB	physopul
	Prunus serotina	black cherry	Nt TREE	prunsero
	Rosa caralina	pasture rose	Nt SHRUB	rosacaro
	ROSA MULTIFLORA	multiflora rose	Ad SHRUB	rosamult
	Rasa setigera	prairie rose	Nt SHRUB	rosaseti
	Rubus flagellaris	common dewberry	Nt SHRUB	rubuflag
	Rubus occidentalis	black raspberry	Nt SHRUB	rubuocci
	Rubus pensilvanicus	yankee blackberry	Nt SHRUB	rubupens
Rubiaceae	*Cephalanthus occidentalis*	buttonbush	Nt SHRUB	cephocci
	Diadia teres	buttonweed	Nt A-FORB	diodtere
	Galium aparine	annual bedstraw	Nt A-FORB	galiapar
	Galium circaezans	wild licorice	Nt P-FORB	galicirc
	Galium cancinnum	shining bedstraw	Nt P-FORB	galiconc
	Galium triflorum	sweet-scented bedstraw	Nt P-FORB	galitrif
	Haustania nigricans	narrow-leaved bluets	Nt P-FORB	housnigr
Rutaceae	*Ptelea trifaliata*	hop tree	Nt SHRUB	pteltrif
Salicaceae	*Papulus deltaides*	cottonwood	Nt TREE	popudelt
	Salix caraliniana	Ward's willow	Nt TREE	salicaro
	Salix interiar	sandbar willow	Nt SHRUB	saliinte

Appendix C

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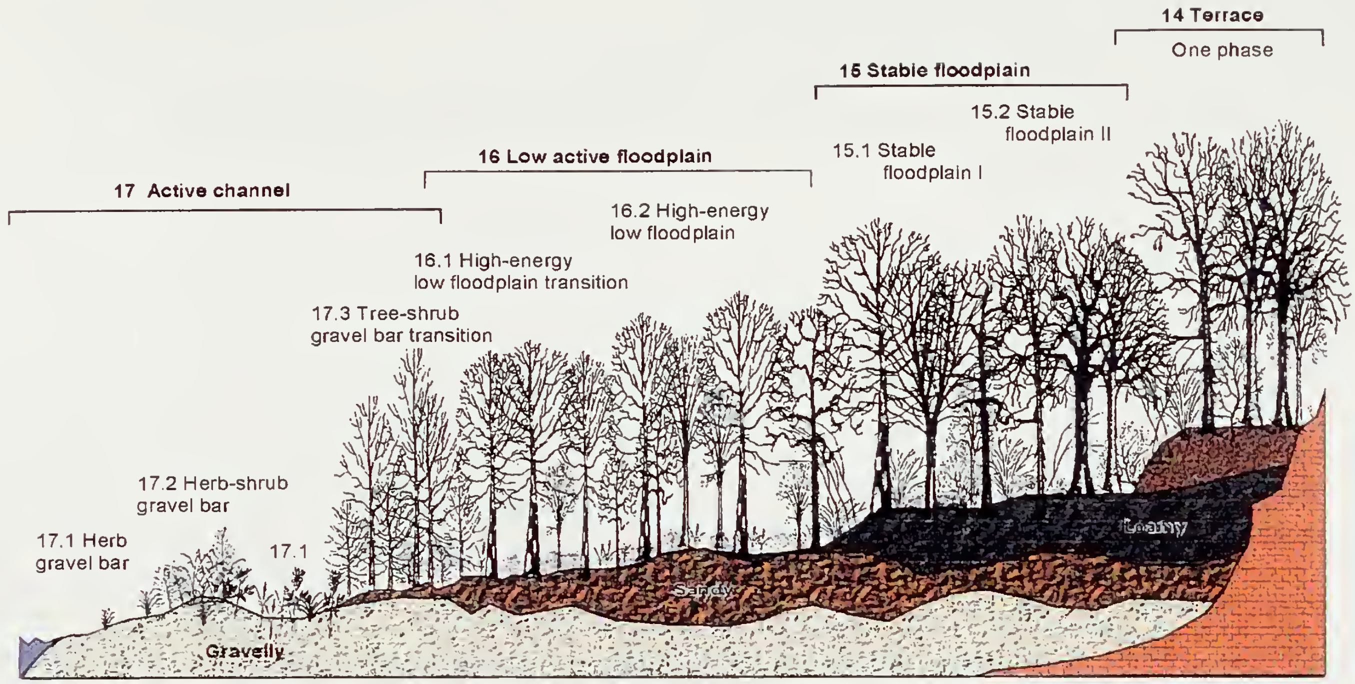
Riverine ELT and ELTPs of the Ozark National Scenic Riverways.


14 Terrace
One phase
15 Stable floodplain
15.2 Stable floodplain II
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16 Low active floodplain
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17 Active channel
17.3 Tree-shrub gravel bar transition
17.2 Herb-shrub gravel bar
17.1 Herb gravel bar
17.1
Loamy
Sandy
Gravelly

Names and brief definitions of ELTs and ELTPs

ELT/ELTPs	Geo-landform	Soils	Vegetation	Comment
14 River terraces (Poorly studied; no current phases)	River terraces	Deep, alfic or ultic colluvium	Mixed oak-sugar maple-bitternut hickory/spicebush mesic forest	Many cleared in region; small isolated remnants; common mesic upland species
15 Stable (high) river floodplains				
15.1 Stable floodplain I	High river floodplains (T_2/T_3)	Deep, loamy, mollic	Mixed hardwood bottomland forest	Elm, hackberry, floodplain generalists > 15.2
15.2 Stable floodplain II	High river floodplains (T_2/T_3)	Deep, loamy, mollic	Mixed hardwood bottomland forest	Oak, sugar maple, mesic bottomland species > 15.1
16 Active low floodplains				
16.1 High energy, low floodplain transition	Low river floodplains (T_2)	Deep, sandy, mollic	Sycamore riverfront bottomland forest	Earlier succession; sycamore, willow, gravel bar and riverside species > 16.2
16.2 Low floodplain	Low river floodplains (T_2)	Deep, sandy, mollic	Sycamore-elm- hackberry riverfront forest	Later succession; elm, hackberry, floodplain generalists > 16.1
17 Active channel				
17.1 Barren-herb gravel bar	Active channel/ gravel bar (T_0/T_1)	Deep, very gravelly sand, entic	Barren to densely herbaceous gravel bar	Few woodies; common gravel bar species
17.2 Herb-shrub gravel bar	Active channel/ gravel bar (T_0/T_1)	Deep, very gravelly sand, entic	Shrub-herb thicket gravel bar	Common young willow and sycamore
17.3 Tree-shrub gravel bar transition	Active channel/ gravel bar (T_0/T_1)	Deep, very gravelly sand, entic	Sycamore-willow young tree gravel bar	Young timber on thin sands at edge of bar

Descriptions of Riparian ELTs and ELTPs.

ELT 17: Active Channel

ELT 17 includes the variants within the annually flooded active channels along the Ozark rivers. ELTPs are differentiated in soil development, distance from and elevation above the river channel, and vegetation. The different vegetative communities associated with each phase reflect the relative differences in protection afforded from the intense spring floods.

ELTP 17.1: Barren to Herbaceous gravel bar

General Description

Barren to herbaceous and woody, vine-dominated vegetation community on gravel bars. Typically found at the river's edge, often located away from the river's edge behind a dense thicket of pole-sized willow, sycamore, and river birch saplings.

Landscape Position

T_0 surfaces (gravel bars) annually flooded, and typically located at the river's edge. Also encountered on gravel bar islands and along chute channels receiving high water flow. Present in all landtype associations (LTAs) of the Current River Hills (CRH) subsection.

Soils

Parent material is deep (> 48 in) gravelly alluvium. Little or no soil development has occurred. This material is 80% gravel and 20% loose sand.

Vegetation

Overstory

Overstory and shrub species are not present.

Ground Flora

The ground flora consists of a sparsely to densely vegetated ground flora of woody vines, forbs, and woody seedlings. Total richness and total cover are typically low. The Active Channel species group is dominant. Exotics of bare-waste grounds often present.

ELTP 17.2: Herbaceous-Shrub gravel bar

General Description

A dense thicket of closely spaced, pole-sized sycamore, willow, and river birch saplings located near the river's edge on gravel bars. This community varies in extent from a narrow band of trees at the edge of a bare gravel bar to patches of variable size and extent within the active channel system.

Landscape Position

T_0 surfaces (gravel bars) annually flooded, typically located near the river's edge. Also encountered on gravel bar islands. Present in all LTAs of the CRH subsection.

Soils

Parent material is deep (> 48 in) gravelly alluvium. Deposition was so recent that little or no soil development has occurred. This material is 80% gravel and 20% loose sand.

Vegetation

Overstory

Overstory-sized species are typically not present. Top-killed and flood-damaged toppled trees are common.

Understory

The understory is dominated by pole-sized sycamore, willow, and river birch saplings. Richness is typically low; the intense flooding disturbance affects establishment by all but flood-tolerant seedlings.

Ground flora

The ground flora is dominated by the Active Channel species group, with some Riverfront species present at low abundance. Common species include *Justicia americana and Polygonum spp.* as well as *Platanus americana* and *Salix caroliniana* seedlings. Total richness and cover are greater than on ELTP 17.1, but richness is lower than on ELTP 17.3.

Differences from similar ELTPs

ELTP 17.2 differs from ELTP 17.1 by the presence of an established sapling and shrub layer and from ELTP 17.3 by the absence of an overstory. 17.2 is generally located closer to the river's edge than 17.3.

ELT 17.3: Tree-Shrub gravel bar-transitional GB-LFP zone

General description

Sycamore-dominated community found within the active zone where gravel bars and low floodplains form a complex landform mosaic. ELTP 17.3 are T_0 surfaces (gravel bars) subject to annual flooding. Enough protection is afforded by the position to allow the persistence of overstory trees.

Landscape Position

T_0 surfaces (gravel bars) annually flooded and typically located within the transitional active zone where both gravel bars and low floodplains are present. ELTP 17.3 is located the farthest from and above the river of the phases within ELT 17. Present in all LTAs within the CRH subsection.

Soils

Parent material is deep (> 48 in) gravelly alluvium. Deposition was so recent that little or no soil development has occurred. This material is 80% gravel and 20% loose sand. The surface is often pockmarked with scour holes and deposition mounds, evidence of the severity of flooding.

Vegetation

Overstory

Sycamore-dominated overstory characterized by sycamore, box elder, and elm species. Total basal area and trees/acre are low, reflecting the dynamic nature of the flooding disturbance affecting the position. Top-killed and flood-damaged toppled trees are common.

Understory

The understory is dominated by pole-sized sycamore and/or willow saplings. The understory is very dense, with an average of 3,500 trees/acre.

Ground flora

The ground flora is composed of Active Channel and Riverfront species. Common species include *Uniola latifolia*, *Saportea officianalis*, *Solidago gigantea*, and *Toxicodendron radicans*.

ELT 16: Active Low Floodplain

The active low floodplain serves to contain the high-energy flood waters associated with out-of-bank flooding. However, not all positions within the active low floodplain are subject to the same levels of flooding intensity and duration. The ELTPs describe the variability in both the physical environment, i.e., distance from and elevation above river, soil development, and the vegetation that characterize the low active floodplains.

ELTP 16.1: High-Energy Low Floodplain-GB/LFP transitional zone

General Description

T_1 and T_2 surfaces (low floodplains) present in the transitional active zone where gravel bars and low floodplains form a complex landform mosaic. A sycamore-willow community is present. Downed trees and flood debris are common.

Landscape Position

T_1 and T_2 surfaces (low floodplains) present in the transitional active zone where gravel bars and low floodplains form a complex landform mosaic. This zone of the riparian corridor is subject to a flooding regime that ranges widely in severity given the seasonal extremes. ELTPs 16.1 are also present along secondary channels flooded during large flood events. ELTP 16.1 seasonally receives the high-energy flood waters associated with an out-of-bank flood. Surfaces are typically undulating, characterized by scour holes and deposition mounds.

Soils

Parent material is deep (> 48 in) alluvium. Most surfaces have < 15% gravel, and some surfaces have recently deposited sand. Surface horizons are loams, loamy sands, or sands, and subsoils are sands or loamy sands. It is common for subsoils to have > 60% gravel.

Vegetation

Overstory

Two variants to a sycamore-willow community are found. A willow-dominated overstory is present on the T_1 surfaces, and a sycamore-dominated overstory is present on the T_2 surfaces. The overstory trees are still relatively young and are characterized by low DBH values.

Understory

The understory is characterized by a dense thicket of pole-sized sycamore and willow saplings (roughly 2,000 trees/acre). The understory is not as densely vegetated as the understory layer in ELTP 17.3 nor as diverse as ELTP 16.2.

Ground Flora

The ground flora is characterized by broad-leaved forbs and grasses, particularly species in the Riverfront species group. Species in the Active Channel and Bottomland species groups are also present but at low abundance and frequency. Species richness is similar to that of ELTP 17.3, but an obvious increase in total cover is present. Common species include *Ambrosia artemisifolia*, *Aster lateriflorus*, *Laportea canadensis*, *Elymus virginiana*, and *Uniola latifolia*.

ELTP 16.2: High-Energy Low Floodplain

General Description

T_2 surfaces (low floodplains) characterized by a mixed bottomland forest with a dense ground flora of broad-leaved forbs and grasses. These are rich bottomlands that flood frequently and intensely. Recent sand deposits are commonly on the soil surface.

Landscape Position

T_2 surfaces (low floodplains) found at relatively higher and farther positions from the river than ELTP 16.1. Surfaces are typically undulating to linear.

Soils

Parent material is deep (> 48 in) alluvium. Most surfaces have < 15% gravel, and most surfaces have recently deposited sands. Surface horizons are loamy sands, loams, or sands, and subsoils are sands or loamy sands. It is common for subsoils to have > 60% gravel.

Vegetation

Overstory

Mixed bottomland forest of sycamore, American elm, and box elder. A significant increase in basal area (90 sq ft /acre) relative to ELT 17.3 (45 sq ft /acre) mirrored by an increase in stems/acre suggests that the overstory is typically a young stand.

Understory

The understory is characterized by box elder, American elm, and hackberry saplings and the shrub species pawpaw and spicebush. Pawpaw and spicebush are not as abundant in this phase as in the high floodplain and terrace phases.

Ground Flora

The ground flora is dominated by the Riverfront species group, which is comprised of broad-leaved forbs, grasses, and box elder seedling. The Bottomland species group is more prevalent. Common species include *Aster lateriflorus*, *Geum canadensis*, *Silpium perfoliatum*, *Verbesina alternifolia*, *Diarrhena americana*, and *Uniola latifolia*. Total richness and cover are similar to that of ELTP 16.1.

ELT 15: Stable Floodplain

The stable floodplain comprises T_2 and T_3 surfaces (high floodplains) that receive flooding every 2 to 5 years. These features are typically protected from flooding, typically at distances greater than 3.7 m above and 100 m from the river. These are bottomland forests characterized by American elm, box elder, and sycamore, an understory dominated by spicebush and pawpaw rather than the pole-sized saplings present in ELT 16, and a diverse ground flora layer.

ELTP 15.1: Stable Floodplain I

General Description

This high floodplain community is characterized by sycamore and American elm in the overstory, bottomland shrubs and saplings in the understory, and a dense ground flora layer of forbs, grasses, and sedges. These are rich, productive, and fairly stable bottomlands that flood every 2 to 5 years.

Landscape Position

T_2 and T_3 surfaces (high floodplains) located away from and above the river channel that receive flooding every 2 to 5 years. Flooding is often of high intensity, with scouring and deposition of fine-textured sediments common. These positions are likely to be in close proximity to chute channels that overflow during flood events.

Soils

Parent material is deep (> 48 in) alluvium. Surfaces have < 15% gravel, and surface and subsoil horizons are silt loam, sandy loam, or loam that only occasionally contain gravel.

Vegetation

Overstory

The overstory is dominated by large sycamore, box elder, and American elm trees. Bitternut hickory, green ash, and hackberry are scattered throughout the canopy at low abundance. Basal area averages greater than 120 sq ft /acre; stem density averages roughly 120 trees/acre.

Understory

The understory is characterized by a well-spaced understory of box elder, spicebush, and pawpaw. American and slippery elm species and green ash and hackberry saplings are scattered throughout at low abundance. Trees/acre are down considerably from that characterizing ELTPs 16.1 and 16.2, averaging 750 trees/acre.

Ground flora

The ground flora is characterized by species in the Riverfront and Bottomland species groups. Common species include *Carex amphibola*, *Elymus virginicus*, *Laportea canadensis*, *Verbesina alternifolia*, *Viola striata*, and *Poa sylvestris*.

ELTP 15.2: Stable Floodplain II

General Description

This high floodplain community is characterized by box elder and American elm in the overstory and pawpaw and spicebush in the understory. The forest floor is typically covered with a dense, lush cover of wide-leaved forbs, sedges, and grasses.

Landscape Position

T_2 surfaces (high floodplains) subject to low-intensity floods every 2 to 5 years that are located a distance away from and above the river channel. The surface is not characterized by scour holes but is linear to convex in shape.

Soils

Parent material is deep (> 48 in) alluvium. Surfaces generally have < 15% gravel. Surface horizons are silt loam, loam, or sandy loam, and subsoils are loam, loamy sand, or occasionally silt loam. They only occasionally contain gravel.

Vegetation

Overstory

The overstory is characterized by large box elder and/or elm species, with American elm more common than slippery elm. Bitternut hickory, green ash, and hackberry are scattered throughout the canopy at low abundance. Basal area is slightly lower than for ELTP 15.1, decreasing to roughly 100 sq ft /acre.

Understory

Spicebush, pawpaw, and box elder dominant the understory, but hackberry and American elm saplings are also scattered throughout at low abundance. Values for trees/acre and basal area are similar to that of ELTP 15.1.

Ground Flora

Species of the Riverfront and Bottomland species groups characterize the ground flora. There is a slight increase in the importance of Mesic Upland species when compared to ELTP 15.1, primarily in abundance levels. Common species include *Carex jamesii*, *Carex amphibola*, *Festuca obtusa*, *Elymus canadensis*, *Poa sylvestris*, *Rudbeckia laciniata*, *Sambucus canadensis*, *Verbesina alternifolia*, and *Laportea canadensis*.

ELT 14: Terraces

ELTP 14.1: Terraces of Large River Systems

General Description

The most protected positions along a river system characterized by a bottomland forest community. Rarely flooded, considered a surface removed from the flooding regime of the present river system. These are rich, well-drained environments well suited for plant growth.

Landscape Position

T_4 and T_5 surfaces (terraces) characterized by convex to linear surface shape and typically located along the backslope edge of the riparian zone, removed from the current flooding regime. Rarely, if ever, flooded. Protected from flooding by greater distance and height above the river channel than any other riparian ELTP.

Soils

Soils are deep (> 48 in) and formed in alluvium. Surfaces have less than 15% gravel. Surface and subsoil horizons are loam or silt loam.

Vegetation

Overstory

Large bottomland trees characterize the overstory, with bitternut hickory as the dominant species. Hackberry, green ash, oak species, and sugar maple are also common. Basal area averages 150 sq ft /acre, an increase over ELTP 15.2.

Understory

The understory is characterized by a dense layer of spicebush and pawpaw interspersed with green ash and sugar maple saplings. Spicebush and pawpaw comprise more than 75% of the understory, which averaged 3,500 trees/acre.

Ground Flora

Ground flora is dominated by species in the Mesic Upland and Bottomland species groups. Species richness increases significantly relative to other riparian ELTPs. The ground flora is comprised of both mesic bottomland species such as *Carex jamesii*, *Viola striata*, and *Asimina triloba* and *Carya cordiformis* seedlings, and species of mesic dolomite forests, such as *Asarum canadensis*, *Desmodium pauciflorum*, *Ranunculus recurvatus*, *Osmorrhiza longistyles*, and *Phryma leptostachya*.

NOTE: Our understanding of this component of the riparian zone was limited. Most terraces are today in agricultural production. This needs further refinement for a better understanding of the physical environment and vegetation community.

ELTPs—Vegetation and Environment Summaries.

ELTP 17.1: Barren to Herbaceous Gravel Bar

Fluvial landform: Gravel Bar
Surface age: T_0
Parent material and soil family: Gravel and Sand/Alluvium (sandy skeletal entisols)
Distance (m): 16.6 ± 4.0 (range: 0 to 65)
Elevation (m): 2.15 ± 0.22 (range: 1.0 to 4.1)

Ground flora	T Richness: 15 ± 4 (range: 0 to 52) T Cover: 21% (range: 0 to 100%)		
	Species	% mean cover (cover class)	% frequency
Forbs	*Diodea teres*	0.38 (1)	62
	Justicia americana	1.03 (1-2)	46
	Saportea officianale	0.23 (1)	38
	Polygonum spp.	0.12 (R)	43
	Isanthus bracteata	7.73 (3)	23
Woody vines and seedlings	*Platanus occidentalis*	0.07 (R)	31

ELTP 17.2: Herbaceous-Shrub Gravel Bar

Fluvial landform: Gravel Bar
Surface age: T_0
Parent material and soil family: Gravel and Sand/Alluvium (sandy skeletal entisols)
Distance (m): 10.4 ± 2.7 (range: 0 to 29)
Elevation (m): 1.46 ± 0.13 (range: 1.2 to 2.6)

Understory	Mean (+/- SE)	Minimum	Maximum
Richness	2.27 (0.71)	0	9
Basal area (sq ft/acre)	5.74 (3.10)	0	27.31
Trees (#) /acre	2301.82 (1170.69)	0	11920.0

Top 5 understory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Platanus occidentalis	1.8	4.13	881.82	54.6	44.8
Salix caroliniana	1.1	1.39	1185.45	63.6	34.6
Salix rigida	1.0	0.12	136.36	18.2	5.3
Salix interior	1.0	0.04	43.64	18.2	3.5
Betula nigra	1.0	0.02	20.00	18.2	3.1

Ground flora	T richness: 30 ± 8 (range : 4 to 84) T cover: 44% (range: 10 to 76%)		
	Species	% mean cover (cover class)	% frequency
Forbs	*Justicia americana*	21.00 (4)	82
	Diodea teres	1.86 (1-2)	27
	Boehmeria cylindracea	0.55 (1)	55
	Polygonum spp.	1.23 (1-2)	80
Grasses	*Uniola latifolia*	0.50 (1)	45
Woody seedlings and vines	*Salix caroliniana*	4.60 (2-3)	82
	Platanus occidentalis	2.41 (2)	64
	Betula nigra	0.41 (1)	64

ELTP 17.3: Tree-Shrub Gravel Bar-transitional GB-LFP zone

Fluvial landform: Gravel Bar
Surface age: T_0
Parent material and soil family: Gravel and Sand/Alluvium (Sandy Skeletal Entisols)
Distance (m): 22.2 ± 3.3 (range: 3 to 59)
Elevation (m): 2.38 ± 0.25 (range: 0.8 to 4.5)

Overstory	Mean (+/- SE)	Minimum	Maximum
Richness	2.00 (0.44)	0	7
Basal area (sq ft/acre)	20.82 (5.64)	0	84.68
Trees (#) /acre	76.67 (18.70)	0	310.00

Top 5 overstory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Platanus occidentalis	7.0	12.16	40.48	66.7	49.9
Acer saccharinum	6.0	2.98	13.33	23.8	14.1
Ulmus americana	6.8	1.63	6.19	23.8	9.4
Acer negundo	6.4	1.29	5.24	19.0	7.9
Salix caroliniana	6.0	1.00	4.76	19.0	6.6

Understory	Mean (+/- SE)	Minimum	Maximum
Richness	6.00 (0.79)	0	17
Basal area (sq ft/acre)	16.86 (2.93)	0	53.83
Trees (#) /acre	3461.91 (652.48)	0	10040.00

Top 5 understory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Salix caroliniana	1.4	4.08	1585.71	66.7	27.0
Platanus occidentalis	3.3	6.00	416.19	71.4	19.8
Acer saccharinum	4.7	2.07	84.76	33.3	6.8
Salix interior	2.7	1.11	101.90	38.1	7.0
Hamamalis vernalis	1.1	0.40	305.17	28.6	5.3

Ground Flora	T richness: 50 ± 5 (range: 11 to 95) T cover: 43% (range: 5 to 98%)		
	Species	% mean cover (cover class)	% frequency
Forbs	*Justicia americana*	5.62 (2-3)	43
	Saportea officianalis	0.98 (1-2)	71
	Solidago gigantea	0.38 (1)	71
	Boehmeria cylindracea	0.26 (R-1)	67
Grasses	*Leersia virginica*	0.69 (1)	48
	Uniola latifolia	1.59 (1-2)	90
Woody seedlings and vines	*Salix caroliniana*	1.52 (1-2)	71
	Platanus occidentalis	1.90 (1-2)	62
	Ulmus americana	0.26 (R-1)	86
	Toxicodendron radicans	5.17 (2-3)	71

16.1: High Energy Low Floodplain-GB/LFP transitional zone

Fluvial landform: Low Floodplain
Surface age: T_1 and T_2
Parent material and soil family: (T1) Gravel and Sand/Alluvium (Sandy Skeletal Entisols)
(T2) Sand and Gravel/Alluvium, Sand/Alluvium (Coarse Loamy Mollisols and Entisols)
Distance (m): 62.1 ± 11 (range: 0 to 236)
Elevation (m): 2.88 ± 0.22 (range: 0.6 to 5.5)

Overstory	Mean (+/- SE)	Minimum	Maximum
Richness	2.27 (0.37)	0	6
Basal area (sq ft/acre)	48.00 (10.01)	0	214.00
Trees (#) /acre	90.91 (14.79)	0	250.00

Top 5 overstory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Platanus occidentalis	9.4	32.93	51.52	63.6	53.2
Ulmus americana	6.4	3.73	15.15	39.4	14.4
Acer negundo	6.3	2.15	8.79	36.4	9.6
Acer saccharinum	10.6	2.46	3.03	18.2	4.7
Salix caroliniana	6.5	1.01	3.94	15.2	4.4

Understory	Mean (+/- SE)	Minimum	Maximum
Richness	5.88 (0.75)	0	15
Basal area (sq ft/acre)	14.37 (2.59)	0	64.93
Trees (#) /acre	2195.4 (537.92)	0	16100.00

Top 5 understory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Salix caroliniana	1.7	3.94	964.85	33.3	25.7
Platanus occidentalis	2.9	5.89	492.12	63.6	24.7
Ulmus americana	4.4	1.28	56.36	48.5	6.6
Acer negundo	3.1	1.18	86.67	39.4	6.3
Lindera benzoin	1.1	0.22	203.02	27.3	5.1

Ground Flora	T richness: 57 ± 3 (range: 14 to 106) T cover: 74% (range: 6 to 100%)		
	Species	% mean cover (cover lass)	% frequency
Forbs	*Laportea canadensis*	12.73 (3)	67
	Boehmeria cylindracea	1.06 (1-2)	55
	Rudbeckia laciniata	1.70 (1-2)	76
	Viola sororia	0.48 (1)	76
	Verbesina alternifolia	1.44 (1-2)	79
Grasses	*Elymus virginiana*	3.51 (2-3)	76
	Uniola latifolia	2.42 (2)	85
	Leersia virginica	1.21 (1-2)	70
	Muhlenbergia frondosa	1.17 (1-2)	52
Woody vines and seedlings	*Toxicodendron radicans*	1.83 (1-2)	73

ELTP 16.2: High Energy Low Floodplain

Fluvial landform: Low Floodplain
Surface age: T_2
Parent material and soil family: Gravel and Sand/Alluvium (Sandy Skeletal Mollisols and Entisols),
Sand/Alluvium (Coarse Loamy Mollisols and Entisols)
Distance (m): 98.0 ± 15 (range: 18 to 302)
Elevation (m): 3.41 ± 0.29 (range: 0.9 to 6.3)

Overstory	Mean (+/- SE)	Minimum	Maximum
Richness	5.37 (0.43)	0	10
Basal Area (sq ft/acre)	83.22 (8.64)	0	190.91
Trees (#) /Acre	150.00 (12.52)	0	290

Top 5 overstory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Platanus occidentalis	11.6	31.33	34.81	88.9	26.7
Ulmus americana	7.3	11.30	31.85	77.8	17.2
Acer negundo	7.1	6.37	20.37	63.0	11.4
Fraxinus pennsylvanica	10.7	6.18	8.15	29.6	6.1
Celtis occidentalis	6.0	2.63	12.59	33.3	5.8

Understory	Mean (+/- SE)	Minimum	Maximum
Richness	9.89 (0.93)	2	19
Basal area (sq ft/acre)	12.44 (1.60)	0.52	28.25
Trees (#) /acre	1667.41 (205.18)	220.00	3980.00

Top 5 understory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Acer negundo	2.7	1.88	188.89	92.6	11.9
Ulmus americana	4.5	2.42	104.44	63.0	10.7
Lindera benzoin	1.3	0.56	325.19	77.8	10.6
Celtis occidentalis	3.4	1.73	107.41	70.4	9.2
Asimina triloba	1.7	0.99	237.78	51.8	9.1

Ground Flora	T richness: 55 ± 5 (range: 0 to 97) T cover: 71% (range: 0 to 100%)		
	Species	% mean cover (cover class)	% frequency
Forbs	*Laportea canadensis*	9.79 (3)	100
	Rudbeckia laciniata	4.63 (2-3)	100
	Verbesina alternifolia	4.54 (2-3)	96
	Polygonum virginiana	2.23 (2)	92
	Viola striata	3.44 (2)	73
	Geum canadensis	0.92 (1-2)	77
Grasses	*Elymus virginiana*	5.93 (2-3)	92
	Diarrhena americana	3.12 (2)	69
	Uniola latifolia	7.02 (3)	92

ELTP 15.1: Stable Floodplain I

Fluvial landform: High Floodplain
Surface age: T_2
Parent material and soil family: Loam/Alluvium, Loam and Gravel/Alluvium (Coarse Loamy Mollisols)
Distance (m): 105 ± 13 (range: 11 to 173)
Elevation (m): 4.10 ± 0.30 (range: 2.3 to 6.0)

Overstory	Mean (+/- SE)	Minimum	Maximum
Richness	5.47 (0.41)	2	8
Basal area (sq ft/acre)	127.50 (17.14)	24.07	261.27
Trees (#) /acre	119.41 (10.69)	60.00	200.00

Top 5 overstory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Platanus occidentalis	21.2	65.64	21.18	76.5	28.3
Acer negundo	7.4	9.26	26.47	58.8	14.4
Ulmus americana	8.2	6.18	12.94	64.7	8.9
Celtis occidentalis	8.9	5.58	10.59	47.1	7.8
Ulmus rubra	9.3	5.46	9.41	47.1	6.8

Understory	Mean (+/- SE)	Minimum	Maximum
Richness	7.64 (0.71)	3	14
Basal area (sq ft/acre)	11.07 (1.23)	2.52	18.65
Trees (#) /acre	1858.82 (226.07)	360.00	3380.00

Top 5 understory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Asimina triloba	2.0	2.91	543.53	76.5	21.8
Lindera benzoin	1.3	0.91	560.00	70.6	15.9
Acer negundo	4.0	2.04	95.29	94.1	11.9
Celtis occidentalis	2.8	0.96	84.71	88.2	8.3
Ulmus rubra	3.0	1.06	87.05	47.1	6.8

Ground Flora	T richness: 45 ± 5 (range: 17 to 91) T cover: 86% (range: 26 to 100%)		
	Species	% mean cover (cover class)	% frequency
Forbs	*Laportea canadensis*	17.53 (4)	100
	Verbesina alternifolia	6.15 (2-3)	100
	Viola striata	2.62 (2)	94
	Polygonum virginiana	1.29 (1-2)	94
	Rudbeckia laciniata	2.26 (2)	76
Grasses	*Elymus virginiana*	17.3 (4)	88
	Poa sylvestris	3.91 (2)	88
Sedges	*Carex amphibola*	2.06 (2)	94

ELTP 15.2: Stable Floodplain II

Fluvial landform: High Floodplain
Surface age: T_2
Parent material and soil family: Loam/Alluvium (Coarse Loamy Mollisols), Silt/Alluvium (Fine Silty Mollisols)
Distance (m): 114 ± 11 (range: 38 to 289)
Elevation (m): 3.90 ± 0.32 (range: 1.0 to 7.9)

Overstory	Mean (+/- SE)	Minimum	Maximum
Richness	5.36 (0.411)	2	9
Basal area (sq ft/acre)	104.69 (11.84)	17.49	229.52
Trees (#) /acre	138.00 (12.94)	30	350

Top 5 overstory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Acer negundo	8.9	21.18	41.20	80	22.7
Platanus occidentalis	19.2	25.30	8.80	44	12.8
Ulmus americana	9.0	10.97	18.80	60	12.2
Celtis occidentalis	9.9	8.40	10.80	48	8.5
Carya cordiformis	10.5	4.59	6.80	40	5.2

Understory	Mean (+/- SE)	Minimum	Maximum
Richness	7.16 (0.78)	2	16
Basal area (sq ft/acre)	10.76 (1.20)	0.30	26.70
Trees (#) /acre	1713.60 (212.88)	60.00	3500.00

Top 5 understory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Asmina triloba	1.8	2.96	621.60	72	24.6
Lindera benzoin	1.3	0.73	431.20	68	13.8
Acer negundo	3.6	2.16	136.00	76	12.9
Celtis occidentalis	2.9	0.77	80.00	68	7.1
Vitis spp.	4.4	0.98	47.20	64	6.9

Ground Flora	T richness: 45 ± 3 (range: 25 to 82) T cover: 87% (range: 3 to 100%)		
	Species	% mean cover (cover class)	% frequency
Forbs	*Laportea canadensis*	18.36 (4)	100
	Rudbeckia laciniata	4.55 (2-3)	96
	Verbesina alternifolia	5.18 (2-3)	96
	Polygonum virginiana	1.30 (1-2)	92
	Viola striata	3.96 (2)	88
Sedges	*Carex amphibola*	1.10 (1-2)	92
	Carex jamesii	3.98 (2)	76
Grasses	*Elymus canadensis*	19.67 (4)	100
	Festuca obtusa	2.36 (2)	85
	Poa sylvestris	2.82 (2)	88
	Cinna arundinacea	1.04 (1-2)	66

ELTP 14.1: Terraces

Fluvial landform: Terrace
Surface age: T4 and T5
Parent material and soil family: Loam/Alluvium (Coarse Loamy Alfisols), Silt/Alluvium (Fine Silty Alfisols)
Distance (m): 161 ± 23 (range: 120 to 204)
Elevation (m): 7.72 ± 0.37 (range: 7.3 to 8.8)

Overstory	Mean (+/- SE)	Minimum	Maximum
Richness	7.50 (0.66)	6	9
Basal area (sq ft/acre)	147.88 (16.03)	111.03	182.66
Trees (#) /acre	160.00	80.00	220.00

Top 6 overstory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Carya cordiformis	19.0	44.57	20.00	75	17.9
Acer saccharum	9.2	10.41	20.00	75	12.1
Fraxnus pennsylvanica	12.4	20.18	22.50	50	11.1
Nyssa sylvatica	13.1	18.63	15.00	75	11.0
Aesculus glabra	4.1	2.51	22.50	25	6.5
Quercus muhlenbergii	13.9	8.91	7.50	75	6.3

Understory	Mean (+/- SE)	Minimum	Maximum
Richness	14.8 (0.47)	14	16
Basal area (sq ft/acre)	13.92 (0.85)	11.68	15.28
Trees (#) /acre	3720.00 (246.71)	3040	4220

Top 5 understory species	Mean DBH (inches)	Mean basal area (sq ft/acre)	Mean trees/acre	% frequency	Importance value
Lindera benzoin	1.1	1.32	1100.0	100.0	15.3
Carpinus caroliniana	2.3	2.16	290.0	100.0	10.0
Ulmus rubra	1.2	1.01	645.00	75.0	9.9
Aesculus glabra	2.8	2.51	230.00	75.0	9.8
Cornus florda	4.8	2.83	95.00	75.0	9.3

Ground Flora	T richness: 77 ± 6 (range: 65 to 90) T cover: 54% (range: 36 to 76%)		
	Species	% mean cover (cover class)	% frequency
Forbs	*Asarum canadensis*	1.50 (1-2)	100
	Desmodium glutinosum	0.75 (1)	75
	Desmodium pauciflorum	1.50 (1-2)	100
	Viola striata	1.50 (1-2)	100
	Phryma leptostachya	0.37 (1)	100
	Ranunculus recurvatus	0.13 (R)	75
Sedges	*Carex jamesii*	1.50 (1-2)	100
Woody seedlings and vines	*Asimina triloba*	1.50 (1-2)	100

Frequency distribution of individual species comprising the Riparian Species Groups (SG) amon ELTPs. For those species present in > 60% of the plots of an ELT, % mean cover is also given (i parentheses). Species code names and associated information are listed in Appendix B.

		ELT 14 Terraces	ELT 15 Stable Floodplains		ELT 16 Active Low Floodplains		ELT 17 Active Channels		
		14.1 Terraces	**15.2 Stable floodplain II**	**15.1 Stable floodplain I**	**16.2 Active low floodplain**	**16.1 Transitional high-energy low floodplain**	**17.3 Tree-shrub gravel bar transition**	**17.2 Herb-shrub gravel bar**	**17.1 Herbaceou gravel bar**
Mesic Upland SG	asarcana	1.00 (2)	0.40	0.47	0.46	0.09	0.00	0.00	0.00
	carycord	1.00 (1)	0.60 (0.5)	0.35	0.27	0.15	0.05	0.00	0.00
	desmpauc	1.00 (2)	0.16	0.06	0.08	0.09	0.05	0.00	0.00
	careblan	1.00 (1)	0.60 (0.5)	0.47	0.54	0.21	0.19	0.09	0.00
	osmolong	0.50	0.12	0.24	0.19	0.24	0.33	0.36	0.38
Bottomland SG	sanigreg	0.75 (0.5)	0.48	0.41	0.54 (1)	0.18	0.05	0.00	0.00
	carejame	1.00 (2)	0.76 (4)	0.94 (1)	0.38	0.21	0.05	0.00	0.00
	festobtu	0.75 (0.5)	0.76 (2)	0.76 (2)	0.69 (1)	0.24	0.24	0.09	0.00
	crypcana	0.50	0.68 (2)	0.65 (1)	0.65 (1)	0.45	0.24	0.09	0.15
	asimtril	1.00 (2)	0.80 (1)	0.82 (2)	0.62 (1)	0.36	0.10	0.00	0.00
	violstri	1.00 (2)	0.88 (1)	0.94 (3)	0.73 (3)	0.36	0.10	0.00	0.00
	geumcana	1.00 (0.5)	0.68 (0.5	0.59	0.77 (1)	0.45	0.29	0.09	0.00
	careamph	0.75 (0.5)	0.92 (1)	0.94 (2)	0.77 (0.5)	0.52	0.33	0.00	0.00
	lindbenz	1.00 (2)	0.44	0.41	0.31	0.36	0.29	0.00	0.08
	polyvirg	1.00 (0.5)	0.92 (1)	0.94 (1)	0.92 (2)	0.48	0.29	0.09	0.00
Riverfront SG	lapocana	1 (1)	1.00 (18)	1.00 (18)	1.00 (10)	0.67 (13)	0.57	0.18	0.00
	elymvirg	0.00	1.00 (20)	0.88 (17)	0.92 (6)	0.76 (4)	0.43	0.09	0.23
	verbalte	0.75 (0.5)	0.96 (5)	1.00 (6)	0.96 (5)	0.79 (1)	0.62 (0.5)	0.18	0.08
	acernegu	1.00 (0.5)	0.92 (1)	0.94 (0.5)	0.85 (1)	0.88 (0.5)	0.57	0.36	0.15
	chaslati	0.25	0.60 (1)	0.53 (7)	0.92 (7)	0.85 (3)	0.90 (2)	0.45	0.23
	rudblaci	0.25	0.96 (5)	0.76 (2)	1.00 (5)	0.76 (2)	0.52	0.36	0.08
	leervirg	0.25	0.64 (1)	0.88 (1)	0.77 (2)	0.70 (1)	0.48	0.18	0.08
	astelate	0.75 (0.5)	0.40	0.71 (0.5)	0.27	0.33	0.43	0.36	0.54
Active Channel SG	isanbrac	0.00	0.00	0.00	0.00	0.30	0.24	0.00	0.23
	diodtere	0.00	0.00	0.00	0.00	0.30	0.43	0.27	0.62 (0.5)
	betunigr	0.00	0.00	0.00	0.08	0.30	0.33	0.64 (0.5)	0.00
	justamer	0.00	0.00	0.00	0.08	0.21	0.43	0.82 (21)	0.46
	lipplanc	0.00	0.00	0.00	0.04	0.24	0.29	0.64 (0.5)	0.08
	platocci	0.00	0.00	0.06	0.00	0.58	0.62 (0.5)	0.64 (3)	0.31
	salicaro	0.00	0.00	0.00	0.00	0.30	0.71 (0.5)	0.82 (5)	0.31